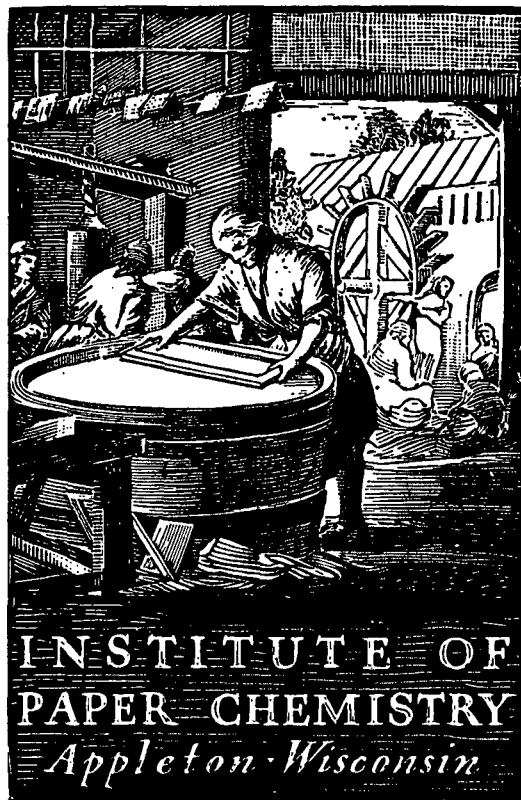


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GENETIC IMPROVEMENT OF LARCH

Project 3409

**Report Two
A Progress Report
to**

MEMBERS OF GROUP PROJECT 3409

March 5, 1982

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

GENETIC IMPROVEMENT OF LARCH

SUMMARY

Emphasis on parent tree selection this past year continued to be a little greater on European larch. Plantations in Wisconsin, Pennsylvania, and Maine were visited, and 13 new European and 10 Japanese larch were added, increasing the total number of selected parent trees to 83. Rooting and grafting investigations demonstrated that conventional rooting procedures, although adequate for young seedlings, were not appropriate for use with older trees. The first twenty grafted clones were placed in the scion arboretum this past spring; 27 additional clones have been grafted and will be added to the arboretum this spring.

Several new seed orchard requests were received, and the number presently stands at twelve. Described in the report are guidelines for the location and establishment of seed orchards. An important strength of the program is the establishment of a number of scattered orchards that will allow the exchange of seed and result in an overall adequate supply.

Research on developing an isozyme system that will allow evaluation of "relatedness" of parent trees continues to make progress. Collection, storage, and extraction procedures are still under investigation. Twenty-five enzymes have been investigated; of the nine showing appropriate activity, peroxidase, cytochrome oxidase, glutamic-oxalacetic transaminase (GOT), leucine amino peptidase (LAP), acid phosphatase, and malate dehydrogenase show the most promise.

Several newly established Lake States plantings were evaluated. Good survival and rapid early growth have been obtained when site drainage is adequate

and vegetative competition is controlled. Larch is more sensitive to herbicides than most conifers. Adequate site preparation rather than plantation release is recommended. The two most promising herbicides for site preparation are Roundup (glyphosate) and Velpar (hexazinone). European larch plantings visited in New York and Pennsylvania demonstrated good survival and rapid growth (2 cords/acre/year) and have turned out to be a source of numerous potentially valuable parent trees.

The cooperative program's first two replicated field plantings were established this past spring and summer. Both were container plantings, and both were in fields where red pine had been planted and part of the planting had failed. Early groundline injury losses made it desirable to replace trees in one planting. The plantings are designed to introduce previously untested larch sources, provide growth rate information, and serve as a source of future parent trees.

Insect and disease problems of European and Japanese larch continue to be reviewed through both field observations and a literature review. No new problems have developed. Larch sawfly and larch casebearer are the most serious insect problems, and both have reasonable solutions. Needlecast disease and associated reduced growth continue to be observed in plantings in northeast Iowa and near LaCrosse, Wisconsin, and appear to be correlated with seed origin.

Wood quality evaluations of Japanese and European larch continued with additional observations being made on selected tree increment cores. Measurements included specific gravity, fiber length, and extractives. Fiber length appears to be similar for the two species, whereas Japanese larch, in preliminary measurements, had a lower specific gravity and higher levels of extractives. Limited numbers of samples make these conclusions somewhat tentative.

The previously reported larch/jack pine pulping study in which 18- to 23-year-old European, Japanese, and hybrid larch were being compared with a 55-year-old local commercial source of jack pine was completed. A summary of the Japanese larch pulping work is included in this year's report. Pulp yields of Japanese larch, although modestly lower than the previously discussed European and hybrid larch, were slightly higher than jack pine, with unscreened kappa 30 yields of 45.7 vs. 43.8%. Cooking rates were modestly slower than jack pine, and conventional pulp strength tests revealed Japanese larch pulp had strength properties similar to jack pine but was a little more difficult to beat when developing breaking length. The lower yield and higher bleaching requirements appear to be associated with higher hot-water extractives.

Plans for 1982-83 include parent tree selection, selection index development, grafting of parent trees, establishment of replicated field plantings, herbicide evaluation, isozyme research, and expansion of wood quality baseline information.

INTRODUCTION

Predictions concerned with softwood wood and fiber supplies in the United States continue to stress that a tight supply-demand situation will develop about 1990 and continue through the year 2030 with the imbalance increasing from -2.2 in 1990 to -3.4 billion cubic feet by the year 2030 (1). With the delay in any tree improvement program of four to six years for selection, propagation, and establishment of seed orchards and ten to twelve years as the time required before significant seed production begins, it is clear the first "improved" 2-0 planting stock will not be available for about 18 years. There is a limited amount that can be done to reduce the time between the start of a program and the availability of the first improved seed. Even by stimulation of early flowering and stepping up the selection and propagation program, it appears that a reduction of only two to three years would occur.

This report describes the progress made this past year in the selection, propagation, wood quality evaluation, and pulping investigations underway. Plans include a modest increase in efforts to speed up selection, tree propagation, and the start of research into early flowering methods appropriate for use with larch. Also included in this year's report is a discussion of the work on the use of isozymes in determining the "relatedness" of larch parent trees. Although this work is not officially part of Project 3409, results are included in this year's progress report because of its considerable interest to the larch project.

SELECTION AND PROPAGATION

SELECTED TREES

The selection of additional European and Japanese larch parent trees was again a priority of the larch project. A slight change in the selection process was necessitated by the widespread nature of larch plantings in the Northeast. A decision was made to concentrate on the selection of European larch in 1981 and Japanese larch in 1982. This will allow for a more efficient use of time than would the inclusion of both species at the same time from diverse locations.

The data collected from individual trees during the selection process are being used to arrive at a selection index, i.e., a single numerical rating that will allow a comparison of the parent trees to determine the best individuals. The selection criteria listed in Project 3409, Report One, contribute substantially to the selection index. In addition, four or five dominant and/or codominant check trees growing in close proximity to the selected tree are also measured to give an approximation of the superiority of the selected tree in relation to the remainder of the planting. Combining these data into one number will allow a useful comparison of potential parent trees regardless of site.

The U.S. Forest Service has again allowed us access to larch selections in their arboretum on the Harshaw Farm near Rhinelander, Wisconsin. Nine Japanese larch and six European larch were obtained from the USFS this past spring. One additional Japanese larch and seven European larch were selected from field plantings on cooperator lands in Pennsylvania (Hammermill Paper Co.) and Maine (Scott Paper Co.). Offers to exchange materials were made by two tree improvement programs in Canada as well as from cooperators in Europe.

Selections have been made from most of the suitable Lake States plantings that are over 15-20 years of age. As the various local selections are grafted and added to our arboretum, more selections will be sought from foreign cooperators to add to the diversity of existing selections.

Selections will continue to be made in 1982, primarily from the Northeast. Japanese larch will receive greater selection emphasis, although it is anticipated that a number of European larch will also be added. Additional larch plantings in the Lake States will be visited and, where possible, parent tree selections made. Presently, we have made 46 European larch selections and 37 Japanese larch selections, and, as indicated in the section that follows, propagation is under way. See Table I for parent tree selections made in 1981.

TABLE I
1981 LARCH PARENT TREE SELECTIONS

Parent Tree Numbers ^a	Location	Collector
LD-1-81 - LD-6-81	Rhineland, WI	U.S.F.S.
LD-7-81 - LD-11-81	Warren, PA	IPC
LD-12-81 - LD-13-81	Somerset County, ME	IPC
LL-1-81 - LL-11-81	Rhineland, WI	U.S.F.S.
LL-12-81	Rumford, ME	IPC

^aSee Appendix for description of code; for greater detail on geographic location see Appendix Tables XIV and XV.

GRAFTING AND ROOTING

Asexual propagation is an important initial phase of the larch project. Once a prospective parent tree has been selected, its identity is preserved by

grafting and placement in an arboretum. The arboretum will serve as a source of scion material for future grafts of the individual parent trees. It eliminates repeated collections from the original selection when scion material is needed, which is often a difficult and expensive undertaking.

The first collection of grafted clones was placed in an arboretum at the Greenville nursery this past spring. Fifteen clones of Japanese larch and five clones of European larch were planted, and an additional 27 clones will be added this coming spring. A number of clones have been grafted that lack sufficient numbers to be outplanted but will be increased during this year's grafting program.

Another aspect of larch propagation being investigated is the rooting of cuttings. Juvenile larch roots quite readily, but success declines rapidly as the age of the cutting source increases. In addition, rooted cuttings from mature larch exhibit plagiotropism (see glossary).

Despite the above apparent problems, rooting could help solve the production problem of needed large numbers of individuals. Rooted cuttings could be planted with grafts of the same clone, thus making a larger number of ramets available in a shorter period. Rooting also has the advantage of extending the propagation time beyond the few weeks available each spring for grafting.

Initial rooting experiments have been hampered by repeated mechanical failures of our growth chamber that finally resulted in a complete change of air, gas, water, and steam supply to the IPC greenhouse. Despite the problems, a number of rooting methods appear promising and will be tried under more controlled conditions this coming spring. Among the treatments to be tested are the position of basal cuts, hormone treatments, storage treatments, and rooting chamber

modifications. Success in rooting dormant season cuttings from mature trees has not been good. The first rooting trial with dormant season larch cuttings was lost to an equipment malfunction. An additional rooting trial will be initiated to reexamine this possibility under more controlled conditions.

It was mentioned previously that the age of the stock plant is an important factor in rooting success. Methods of restoring a juvenile growth state and therefore improving rooting will be tried. One such method is to heavily cut back a grafted or rooted individual to form a number of shoots. The resulting shoots may be capable of increased rooting or may need to be "hedged" again to improve rooting. Repeated hedging improves rooting of many hard-to-root species and will be tried with both larch grafts and rooted individuals. A second method suggested by a French visitor is to graft using scion material taken from a previous graft. A succession of grafts using scion material from previous grafts rather than returning to the original stock plant may also restore juvenility.

Both the hedging and grafting methods will be tried this coming year. A number of treatments used in previous rooting trials have shown promise and will be further evaluated for their effectiveness in promoting rooting.

Early experience indicates Japanese larch is going to be easier to propagate than European larch.

SEED ORCHARD PLANS

Establishment of a series of seed orchards on company lands in the Lake States and Northeast is an important aspect and strength of the larch program. Last year's report described the computer-designed, eight-acre clonal seed orchard that is being suggested as the near minimum size for company use. This standard orchard is

designed to have 15-30 clones and 15-30 individuals per clone. Inbreeding is minimized by the orchard design and the use of nonrelated clones.

An estimate of potential seed orchard seed production was made in 1979 using an 18-year-old European larch seedling seed production area, and the results suggest production rates as high as two million seeds per acre are possible in a good seed year. Attempts were made to verify this earlier estimate, but, because of poor seed crops the past two years, this was not feasible. Larch seed production was not only poor in the United States the past two years but, apparently, production was low in Western Europe also. Since seed orchard production is controlled in part by climate, soils, and weather conditions, guidelines have been formulated for the location, establishment, and care of seed orchards. Occurrence of poor seed years further emphasizes the need for the development of a series of widely scattered seed orchards, the development of an informal exchange procedure, and the establishment of appropriate cone collection, extraction, and seed storage procedures.

Guidelines for the location and establishment of a larch clonal seed orchard are similar to those of other conifer species. A useful discussion of the problems associated with seed orchard establishment is given by Faulkner (2). The specific needs of larch seed orchards in the United States are not available but, based upon comments of Mitchell (3) for hybrid larch orchards in England, the following guidelines are suggested:

- (1) Locate on upland, well-drained loam to silt loam sites.
- (2) Isolate from native larch and other larch plantings by approximately 600 yards.
- (3) Locate on level to 3-5% north or northeast aspects (not south or southwest aspects).

- (4) Locate as far south on company lands as reasonable - less chance of frost injury to flowers and a greater number of degree days, thus promoting flowering. An alternative is to take advantage of "lake effect" situations to reduce danger of late spring frosts (see Fig. 1).



Figure 1. Heavy frost damage to six-year-old Japanese larch planted in east Central Wisconsin. Care is required in locating seed orchards containing Japanese larch parent trees.

- (5) Select a site having a medium level of soil fertility - extremely high fertility promotes vegetative growth and reduces flowering.
- (6) Develop a seed orchard management plan that provides for fertilization using a balanced fertilizer twice a year at moderate levels (200-300 lb of 10-10-10 for example). The plan should also provide mouse, rabbit, and deer protection

and for clean cultivation around each tree (area 3-4 feet in diameter) during the first 2-3 years.

- (7) Irrigation is not recommended except perhaps watering once or twice during the first year or two to insure establishment and rapid, early growth. Mowing is acceptable after grafts and/or rooted individuals reach 5-8 feet in height.

The present parent tree selection program allows the establishment of three types of seed orchards: Japanese larch, European larch, and orchards for the production of hybrid seeds. The latter consists of a mixture of European and Japanese larch clones. Interestingly, in the hybrid orchard, there is evidence that, if the hybrid seed is collected from the European larch parent trees, the seedlings will resemble European larch, and, when collected from the Japanese larch clones, they will more closely resemble Japanese larch. To date, the following seed orchards have been requested:

Organization	Type of Orchard
Consolidated Papers, Inc.	Japanese and European
Potlatch Corporation	Hybrid
Scott Paper Company	Japanese, European, and Hybrid
Georgia Pacific Corporation	Hybrid
The Mead Corporation	Hybrid and European
Wisconsin DNR	Hybrid and European
Michigan DNR	Hybrid and European

ISOZYME STUDIES

Background

Isozyme research is only about 20 years old, being first announced in 1959 by Markert and Møller (4). They demonstrated that organisms commonly synthesize

many of their enzymes in several different molecular forms, presumably to fulfill specialized metabolic requirements. All living systems apparently require multiple molecular forms of certain enzymes, known as isozymes, to maximize biological capacity.

Isozymes are frequently identified by electrophoresis and isoelectric focusing and are recognized by differences in mobility in electrophoresis and by their net charge in isoelectric focusing. Isozymes with the greatest net charge, for example, will move fastest toward the electrode of the opposite charge and vice versa. Support media for electrophoresis and isoelectric focusing are polyacrylamide gels or starch gels. In isoelectric focusing, each isozyme collects or focuses at its isoelectric point, resulting in a banding pattern in which each isozyme is clearly resolved from its neighboring isozymes.

Objectives

Maximizing genetic diversity in a breeding population as a hedge against serious insect and disease problems and minimizing inbreeding are two important considerations when selecting parent trees going into a seed orchard. Biochemical studies of isozyme patterns are a way of determining if the trees selected are closely related. To delay establishing seed orchards until progeny testing has been completed on parent trees where the origin is unknown would be a mistake. Therein lie the benefits of isozyme research. Determination of the genetic background may be done at an earlier stage of the tree's development rather than waiting many years to perform progeny tests.

The objective of the isozyme studies is to develop biochemical techniques for evaluating genetic heterozygosity of parent trees and the degree of relatedness among trees going into a seed orchard. The opportunity exists to first evaluate

suitable enzymes and techniques for isolating the isozyme forms and then develop a rapid analysis technique that may even be conducted under field conditions. Most reported work to date has been done on species other than larch, including pine, spruce, and Douglas-fir, but some of the techniques used and enzymes selected may be applicable to larch.

Early Results

Several facets of the study that required investigation included: (1) when to collect, (2) what kind of needles to collect, (3) where in the crown to collect, (4) how to store needles, (5) which enzymes were most suitable for analysis, and (6) needle extraction techniques. To date, mature needles have generally been used rather than newly flushed needles. Other researchers have found that isozyme patterns tend to appear and disappear, relative to the state of development in immature needles. However, with mature needles, one must be wary of senescence in late collections.

To date, no work has been done on the relationship between crown position and isozyme activity. However, Rudin (5) found no indication of changed patterns in any particular position in the crown. Staining intensity, however, was highest for needles exposed to the south, which could be interpreted as a higher metabolic level on the sunny side of the tree. Some work has been done on storage, using both liquid nitrogen and freezer storage, but neither has proven totally satisfactory to date.

Approximately 25 different enzymes have been investigated in the project for their usefulness. Usefulness in this preliminary investigation meant whether they gave any banding patterns at all. Only nine of the enzymes investigated have

shown any isozyme activity. The most promising enzymes to date include: peroxidase, cytochrome oxidase, glutamic-oxalacetic transaminase (GOT), leucine amino peptidase (LAP), acid phosphatase, and malate dehydrogenase. Shown in Fig. 2 is peroxidase banding for Japanese larch half-sibs. Other enzymes with some potential which need to be investigated further include glutamate dehydrogenase and isocitrate dehydrogenase. It would be desirable to have five or six enzymes to characterize parent trees, although one or two good reproducible isozyme patterns may distinguish closely related individuals.

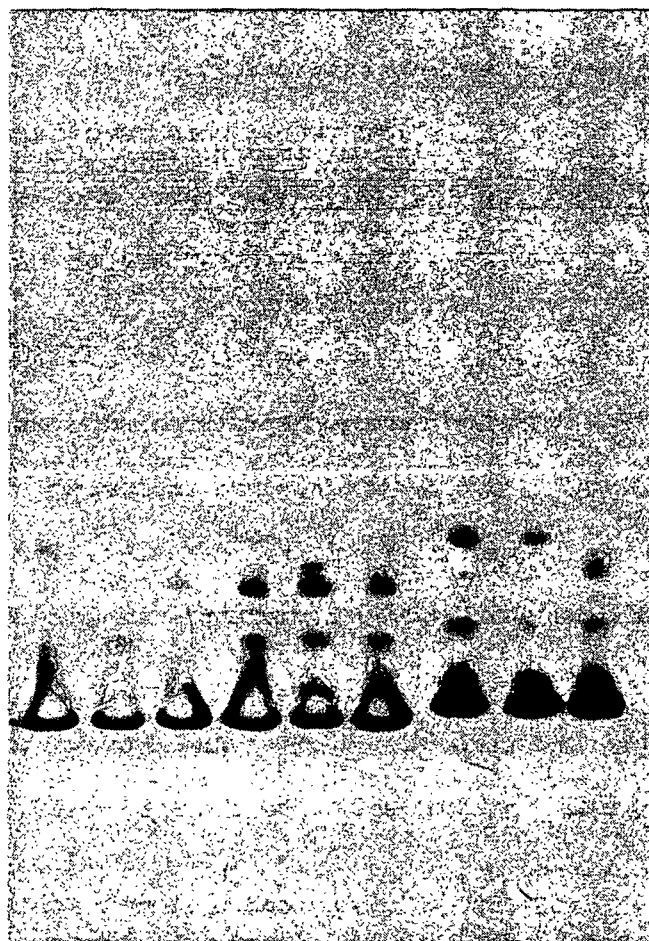


Figure 2. Illustrated is the banding pattern for Japanese larch half-sib populations using peroxidase. Each group of three represents three trees from one seed lot. Differences are apparent between and within seed lots.

Needle extraction methods vary with the enzyme being investigated. Acetone powder and DMSO extraction are the two methods presently being used for the six most promising enzymes. However, several other methods are available and may be useful in the future as new enzymes are investigated. Given in Appendix Tables XVI, XVII, and XVIII are flow diagrams for the isolation and use of the most promising enzymes.

The general approach used has been to investigate potentially useful enzyme systems through electrophoresis and then try the most promising of these in isoelectric focusing. By using a suitable, narrow-range pH gel in focusing, bands can be separated and differences better detected. A densitometer will also be acquired which is suitable for recording accurately the position and intensity of the bands.

Plans

A major effort will be made this winter to check whether differences can be determined between half-sib European and Japanese larch using the six most promising enzyme systems. Needles from these half-sibs have been collected and are being stored in liquid nitrogen. A storage study was made this past summer, checking liquid nitrogen and frozen storage against fresh material at 1 1/2 and 2-month intervals, and it appeared from this preliminary test that liquid nitrogen provided better storage than freezing the needles, but results were not as good as those obtained using fresh needles. Seedlings from the same half-sib populations that are planted at the IPC nursery have also been preserved in pots in the Greenhouse, and this fresh material will also be used to check promising enzymes and in a continuation of the storage study. In addition, samples have been collected from grafts and frozen, and this material will be used to check whether the enzyme systems under consideration show differences between materials of different

geographic origin. Later in the winter, new enzyme systems will be tried, using mature frozen European and Japanese larch needles.

Isozymes show considerable promise as useful tools for probing differences between trees of different geographic origin and possibly even between closely related trees. Needlecast, a disease of some concern in larch breeding work, appears to be more serious in some sources of larch than others. Isozyme analysis may be useful in determining those sources which are more resistant. Eventually, this tool may be used routinely in tree breeding work.

ESTABLISHED FIELD PLANTINGS

LAKE STATES PLANTINGS

A number of small plantings have been established by cooperators during the past two years using container-grown stock. The seed used in producing the stock originated with cooperators in Europe, Japan, and the United States. Seed availability, particularly quality, known-origin seed, has been sporadic and of small quantity. Damaging spring frosts in Europe this past year have again hampered seed acquisition. The several pounds of seed we have stored will all be placed with cooperators this winter.

The plantings that have been established are having the usual establishment problems but appear to be handling them well. Fall-planted container stock that had not been sufficiently hardened off had widespread dieback in one planting. Most plantings on either old-field sites or cutover hardwood sites were having competition problems that appeared to be serious after the first year. Observations during the second year indicated that larch may be capable of handling more competition than first expected, particularly stock that was in good condition and planted properly. Competition is a factor, however, and reduced competition gives larch a much better chance for establishment and rapid early growth. Preliminary herbicide work indicates that larch is quite sensitive to the more commonly used release chemicals, and the chances of coming up with a release chemical appear to be low. What this means is that plantation establishment should center around a well-prepared site rather than attempting to release material after competition develops.

The two most promising herbicides for site preparation are glyphosate (Roundup) and a liquid formulation of hexazinone (Velpar). Other herbicides that

will be evaluated are picloram (Tordon 101) and triclopyr (Garlon). The carry-over of hexazinone, picloram, and triclopyr and their effect on newly planted larch seedlings will also be evaluated this coming year.

Among the plantings visited this past year was a 12-year-old European larch planting established by Michigan Technological University near Houghton, Michigan. The planting was established on an old field that was part of an abandoned farm. Growth has been good, approximately 30-35 feet in height and diameters of up to 8 inches on the better stems, although the spacing appears to be tight (Fig. 3). This planting is one of several we have seen that has been successfully established on old fields with a minimum of site preparation. A two-year-old planting of hybrid larch put in by The Mead Corporation on an old field east of Rapid River, Michigan, is showing good survival and growth. The stock was planted in scalped furrows and, when the area was visited last summer, the grass competition between furrows was extremely heavy. Despite the competition, many observed stems were between two and three feet in height and apparently vigorous.

Several conversion plantings were also visited this past year. A three-year-old European and Japanese larch planting put in by the Michigan Department of Natural Resources near Covington, Michigan, is shown in Fig. 4. Unfortunately, much of the stock for the planting was large and unpruned, making it difficult to handle and plant. On-site pruning was rather crude and contributed to lowered survival. During the first growing season, few stems could be found and many of the live stems were having difficulty recovering. Observations during the latter part of the second growing season and during the third growing season indicated that a number of stems had survived and were beginning to produce good growth. Whether or not the overall stocking will be sufficient is yet to be determined.



Figure 3. A 12-year old planting of European larch established on an old field by Michigan Technological University near Houghton, Michigan. Growth and survival have been good, although, as in most larch plantings observed, spacing is apparently too tight.

Another conversion planting visited was established by Michigan Technological University near Nisula, Michigan. The planting is three years old and has a number of stems that are over four feet (Fig. 5). Most of the material appears to be handling the competition from stump sprouts and nonwoody vegetation with the possible exception of climbing false buckwheat. The buckwheat has entwined itself with almost anything that will lend support, including the larch. Damage occurs from both the shade produced by the leaf area of the buckwheat and the very tight coiling as the buckwheat winds its way up the stem. This coiling may damage succulent leaders as they increase in diameter. Buckwheat has been a problem on a number of sites and is thought to have been introduced through the feed for the draft animals used in early logging.



Figure 4. One of the better 3-year-old European larch growing in a conversion planting established by the Michigan Department of Natural Resources in upper Michigan. Poor stock conditions and handling reduced survival and slowed early growth.

A two-year-old hybrid larch planting established with container stock by Consolidated Papers, Inc. in northern Wisconsin has shown rather mixed results. Part of the planting has individuals that are growing well (Fig. 6), but other areas have low survival. Part of this lessened survival is attributable to heavy grass and aspen sucker competition, but the main factor appears to be poor drainage. Those areas on the site that are low and have a high water table or standing water have very poor survival. Competition from stump sprouts, aspen suckers, and herbaceous material is a factor throughout the site.



Figure 5. A three-year-old European larch planted in upper Michigan on a clearcut northern hardwood site. Growth is being affected by competition from fire cherry and climbing false buckwheat.

Growth and survival would have been improved if chemical site preparation had been employed. However, these initial plantings have considerable value in pointing to both problem areas and successes. As mentioned previously, it appears that good site preparation, rather than later release from competition, is a real key to larch establishment.



Figure 6. A container-grown two-year-old hybrid larch planted by Consolidated Papers, Inc. in northern Wisconsin. The planting was established on a clearcut aspen, balsam fir, black spruce site with heavy returning competition from aspen suckers and nonwoody plants. Best survival and growth occurred in areas of reduced competition and good drainage.

NORTHEAST LARCH PLANTINGS

European and Japanese larch were planted in the Northeast as early as 1925, and numerous plantings were made from 1959 to 1961. Many of these plantings have done well and are now a source of potential parent trees. A number of these

plantings were visited this past year and parent tree selections made. Descriptions of several older larch plantings which illustrate the growth rate of larch in the Northeast also exist in the literature. Described in the paragraphs that follow are illustrations of the growth of larch in the northeastern United States.

Boise Cascade Planting, Rumford, Maine

One interesting plantation visited was near Rumford, Maine (Oxford County, Woodstock Township). This planting is owned by Boise Cascade Corporation and was planted in the spring of 1962 with 2-0 stock from Dave Cook. The stock was a mixture of Japanese and European larch. The planting site has an ESE aspect, a 4% slope, and the soils are a deep sandy loam. The purpose of visiting the area was to look for potential parent trees. One Japanese larch was selected (LL-12-81) that at age 20 had a total height of 66 feet and a diameter at breast height of 10.5 inches (Fig. 7). Five nearby dominant and codominant check trees ranged from 57 to 67 feet in height and from 9.6 to 11.4 inches in diameter. Survival in the planting appeared to be about 80%, and volume measurements taken earlier in the year by Boise Cascade Corporation indicated the planting had a volume of 43.5 cords per acre at age 20.

Scott Paper Company Planting, Waterville, Maine

An older planting visited this past fall was a 50-year-old European larch planting on Scott Paper Company land north of Waterville, Maine, in Somerset County, Solon Township. The planting was on a silt loam soil, north aspect, and in an 8% middle slope topographic position. Two trees were selected from this site (LD-12-81 and LD-13-81). The selected trees averaged 16.3 inches in diameter and 107 feet in height. Nearby dominant and codominant check trees ranged from 11.2 to 16.9 inches in diameter and from 98 to 108 feet in height. This stand provides evidence of the

potential of larch for the production of solid wood products. Measurements made on a number of other trees in the planting by Scott Paper Company indicate the stand had an age 30 average height of 68 feet and an average diameter of 8.8 inches.



Figure 7. A twenty-year-old Japanese larch selected tree (66 feet, 10.5 inches) in a mixed Japanese larch - European larch planting that averaged 43.5 cords/acre. Foresters Sidney Balch (Boise Cascade - left) and David Maass (Scott - right) assisted in selection and measurement of LL-12-81.

Hammermill Paper Company Plantings, Erie, Pennsylvania Area

Several plantings of European larch were visited in Warren and Potter counties south and east of Erie, Pennsylvania. Most of the plantings were 20-21 years old and were growing on low fertility loam and silt loam soils. Survival of the plantings appeared to be 70-80%. Dominant and codominant selected trees ranged from 8 to 12 inches in diameter and 55 to 65 feet in total height. Planting stock for these plantings was obtained from the State of Pennsylvania, and several sites were fall planted. Geographic origin of the planting stock is being investigated,

and, in those cases where selected trees may be related, isozyme techniques will be used to check the degree of relatedness. Figure 8 illustrates a Warren County planting and selected tree. Many rapid-growing trees were examined, and, in at least one instance, red pine planted on the area one or two years earlier were considerably smaller and being overtopped by the larch. Most of the plantings were closely spaced, and it became evident that larch was very sensitive to growing space. Diameter growth, it appears, can be effectively increased by increasing the planting spacing or by early thinning.

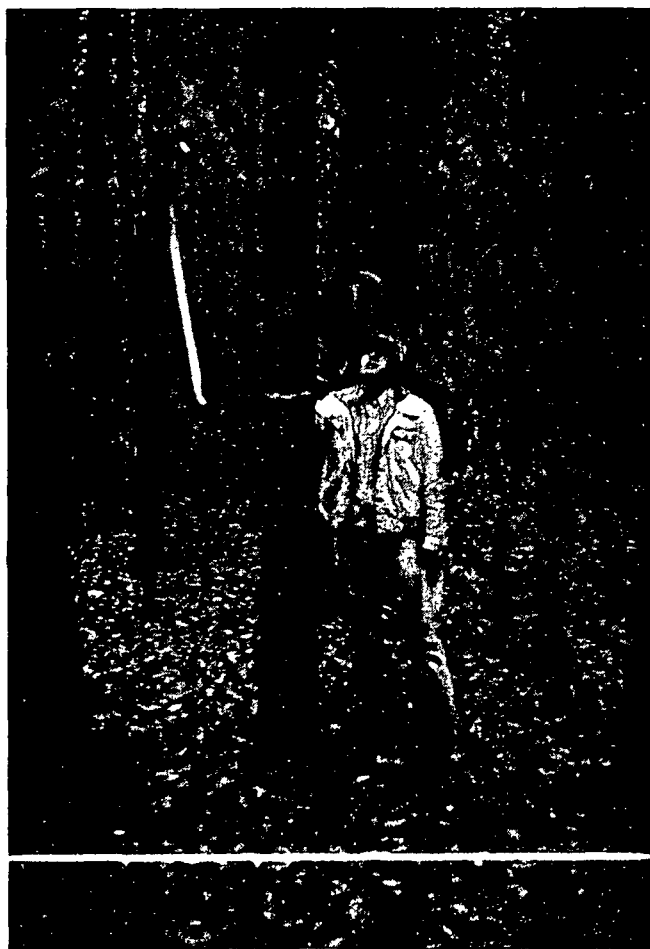


Figure 8. Hammermill forester Jim Hunley evaluating stem straightness of a narrow-crowned, finely branched 22-year-old selected European larch parent tree in Warren County, Pennsylvania.

Early Pennsylvania Plantings

A number of conifer plantations developed in northwestern Pennsylvania from 1925 to 1935 were reevaluated in 1968 by the Northeast Forest Experiment Station (6). Included in these plantings of red pine, jack pine, white pine, Scotch pine, and Norway spruce were several plantings of Japanese and European larch. Between-species volume growth comparisons are not satisfactory because of survival, site, and thinning history differences from plantation to plantation. Examination of height and diameter growth, however, does provide some insight into the potential of larch on upland loam and silt loam soils. Most plantings were not thinned, so diameter growth is less than might be normally expected. Overall, it appears larch has considerable potential for the production of both fiber and solid wood products. Table II illustrates the type of growth obtained on what must be considered unmanaged plantings. There seems to be increasing evidence that Japanese and European larch do well on fairly light, sandy soils and will match red pine growth on these sites. Also, larch can be expected to outgrow red pine and white pine on loam and silt loam soils.

TABLE II

NORTHWESTERN PENNSYLVANIA JAPANESE AND EUROPEAN LARCH PLANTATIONS

Plantation Number	Species	Site Index, feet	Age, years	Measured Number	Dominant and Codominant Trees			
					Mean d.b.h., inches	Annual Dia. Growth, inches	Mean Height, feet	Annual Height Growth, feet
9	JL	73	46	205	9.2	0.20	66.1	1.44
33	EL	86	53	105	11.0	0.21	80.9	1.53
44	EL	63	45	150	7.3	0.16	59.0	1.31
55	JL	90	41	221	10.0	0.24	76.1	1.86
55A	JL	78	41	375	7.8	0.19	63.5	1.55
64	EL	84	46	207	10.4	0.23	78.1	1.70
71	EL	80	47	85	11.0	0.23	69.9	1.49

REPLICATED FIELD PLANTINGS

Replicated trials are being established with interested cooperators to aid in the evaluation of several sources of larch seed on a variety of sites and under different climatic conditions. The trials will provide growth information and will also serve as future sources of parent trees. The trial design is a randomized block with four replications; greater detail can be found in Project 3409, Progress Report One, Page 34.

Two replicated trials were planted this past year, one with Mosinee Paper Co. in northwestern Wisconsin and one with Consolidated Papers Inc. in northcentral Wisconsin. The trial design is illustrated in Fig. 9 and will be used for the trials planted in 1982. The Mosinee planting was put in on June 17 and 18, 1981, about 5 miles east of Gordon, Wisconsin, in Douglas County. The area chosen was an old field that had been planted with red pine but had poor survival. The soil texture in the upper six inches was loamy sand and graded to sand below six inches. A soil nutrient analysis indicated there were no deficiencies of the major elements. The site was sprayed with glyphosate at the rate of three pounds a.i. per acre the fall prior to planting to control the dense quack grass cover. After the herbicide treatment had taken effect, the site was plowed and double disked.

The stock for the planting was grown in styroblocks and was quite succulent and spindly at the time of planting. Although the stock had not been sufficiently hardened off, personnel arrangements and field travel led to the on-site decision to plant the trial. In addition to the problem with stock condition, annual weeds were beginning to reoccupy the disturbed site. In an attempt to reduce competition, a directed spray of Roundup (two pounds a.i./acre) was applied to a four-foot-diameter circle around each tree several weeks after planting. The treatment was effective

but was too late to prevent seed dispersal. An additional herbicide treatment may be necessary this spring.

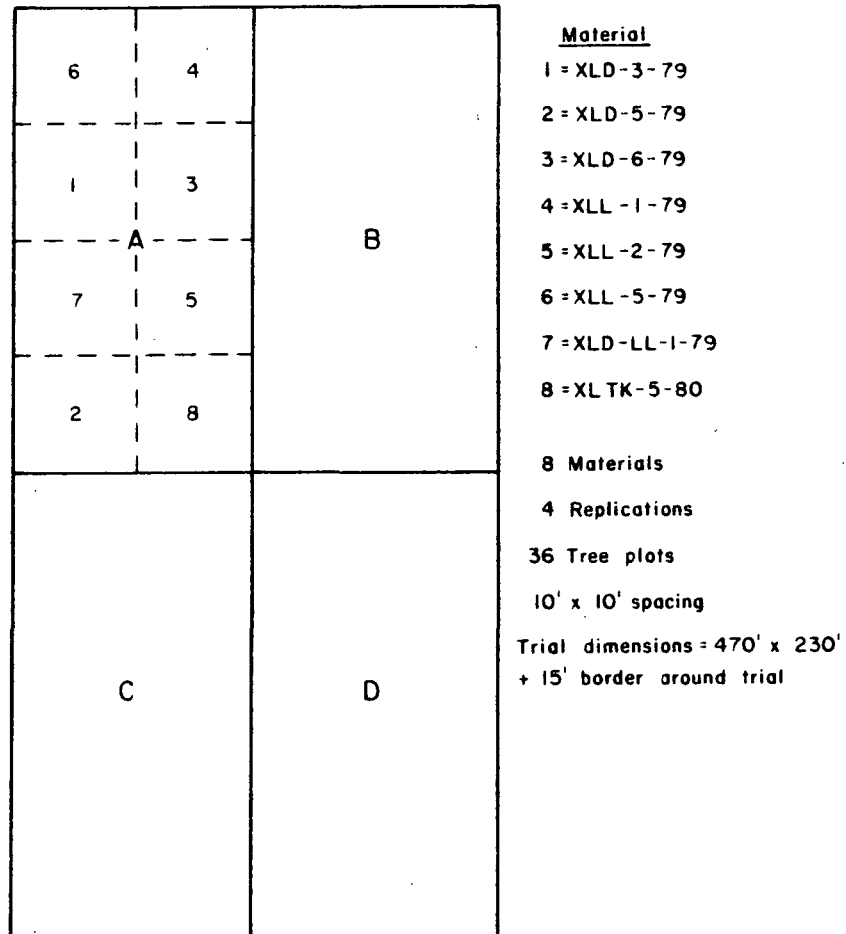


Figure 9. Illustrated is the typical design of a replicated planting.

The trial had an unusually high mortality rate that was directly attributable to the stock condition. A condition known as groundline injury developed as a result of sunlight being reflected off the exposed mineral soil around the trees, which produced very high temperatures that killed the cambium at the groundline. Hardening off of the container stock prior to planting would have reduced groundline

injury. Replacements were planted in late summer, but additional replacements may be needed next growing season.

The second trial established was with Consolidated Papers Inc., eight miles east of Argonne, Wisconsin, in Forest County. The trial was planted in late summer and differed in several respects from the Mosinee planting. The stock for the Consolidated planting was grown in styroblocks but was held for a longer period and consequently was larger and more lignified than that put in by Mosinee. The site was an old field previously planted with red pine that had partially failed. The vegetation was primarily quack grass and was treated with glyphosate (two pounds a.i./acre) seven days prior to planting. The planting site was left undisturbed after treatment, and the stock was planted directly into the sod mat. This approach should reduce the problem of returning annuals and eliminate groundline injury, but it could produce a different set of problems. The sod mat that remains after herbicide treatment inhibits the movement of light rain into the root zone and the mat of dead grass around the stock creates an ideal condition for rodent problems.

A number of plantings established on old fields as part of the Populus program developed the same problems with returning annuals as the Mosinee planting. However, it appears that larch can handle more herbaceous competition than aspen, and the establishment methods used with the first two trials will help determine the site preparation needed for future plantings of larch on old fields.

Five additional replicated trials will be planted this coming spring. Two of the trials, one with Potlatch Corporation and one with Blandin Paper Co., will be established in northern Minnesota. Two additional trials will be planted in upper

Michigan by The Mead Corporation. The fifth trial will be planted in Maine by Scott Paper Co.

A number of additional seed sources will be evaluated in the 1982 replicated trials. All of the trials, previously established and new, have one or more common seed sources that will allow a comparison between trials. Greater-than-average care is being suggested for these trials because of the value of the seed sources and because of the anticipated future value of the material for parent trees.

INSECT, DISEASE, AND ANIMAL DAMAGE

INSECT PROBLEMS OF LARCH

No additional insect problems beyond those listed in Project 3409, Progress Report One, have been noted. Statements by larch growers continue to indicate that the two insects of most concern, the larch sawfly and larch casebearer, can be controlled through a spray program and/or biological control procedures when outbreaks occur.

A potential problem that has been reported with 20 species of pine and seven nonpine species (two ornamental cedars, white and blue spruce, tamarack, European larch, balsam fir) involves the transmission of the pine wood nematode, Bursaphelenchus xylophilus (Steiner and Buhrer) Nickle, by long-horned beetles, causing what is being termed the pine wilt disease. Early symptoms are lack of resin flow from fresh wounds followed by yellowing of the needles in the tree's crown. The entire crown then turns brown and the tree dies. Apparently, the nematode causing the pine wilt disease is native to the U.S., and it is not expected to increase over past levels. Control measures are primarily those of sanitation by removing infested trees before beetles emerge in the spring. Scotch pine is the most common host.*

DISEASE PROBLEMS OF LARCH

The needlecast disease mentioned in Progress Report One was again observed in plantings in Iowa and Wisconsin this past year. The pathologists investigating this disease feel it is caused by a species of the fungus Mycosphaerella. Disease symptoms are evident from late June to September. Needles turn yellow, then light

*Personal communication with Kathryn Robbins, Plant Pathologist, USDA Forest Service, Northeastern Area, State and Private Forestry, St. Paul, Minnesota.

brown, before dropping. New needles may appear on infected branches during the same season that defoliation occurred.

Needlecast symptoms were initially observed and confined to two provenances of European larch growing on the Yellow River State Forest in Iowa. It has now been noted in three 5 to 12-year-old European larch plantings on the Coulee Experimental Forest near La Crosse, Wisconsin (Fig. 10). The severity of the disease is still being investigated, but it is felt that the use of resistant seed sources will minimize effects.



Figure 10. The appearance of the needlecast disease (causal organism, Mycosphaerella sp.) on a 14-year-old planting of European larch near La Crosse, Wisconsin. The disease has also been noted in plantings in Iowa. It is felt that selection of resistant seed sources and parent trees will help minimize disease effects.

The European larch canker, formerly Dasyscypha willkommii (now Lachnellula willkommii) that was reported eradicated after identification in Massachusetts in

the early 1960's has now been found in native tamarack in Maine. A discussion of this disease is on page 69, Progress Report One.

ANIMAL DAMAGE OF LARCH

The principal animal antagonist of larch remains the porcupine. A relatively small number of these animals can cause unacceptable levels of damage, particularly in small plantings. Early detection of porcupine feeding in an area followed by control measures will minimize damage.

Animal pressure (deer, rabbits, etc.) to larch is no greater than that experienced with other tree species. It is felt that the rapid early growth of larch should enable it to outgrow a number of problems in a shorter time than most species. Establishment of larger plantations will also tend to reduce the effects of animal pressure.

WOOD QUALITY AND PULPING

WOOD QUALITY OF SELECTED TREES

As stated in Project 3409, Progress Report One, the wood quality of Japanese and European larch was compared with that of several other commonly pulped native species. This comparison was made through a literature search of the wood quality of mature trees of the species involved. European larch specific gravity averaged 0.49, whereas Japanese larch averaged 0.44. Fiber length for both species averaged 3.6 mm.

Wood quality continues to receive a major amount of emphasis in the larch project. Additional selections of outstanding trees were made in 1981, bringing the totals to 46 European larch and 37 Japanese larch selections. Whenever possible, breast-high, 10-mm increment cores were collected from these trees to check specific gravity, fiber length, alcohol-benzene extractives and hot-water extractives. However, in some cases, it was not possible to take cores, because we either could not obtain permission to remove cores or else we received scions from grafted trees and did not have access to the original tree.

Specific Gravity

Specific gravity is obtained on a green volume basis on the complete core of all four cores taken. Rings 14-16 are then cut from two cores and specific gravity measured again, to give an age 15 specific gravity. Because of a decision to concentrate on selecting European larch in 1981 and Japanese larch in 1982, only one Japanese larch selection was made in 1981 from which cores were available. This was a 20-year-old tree from Maine which had a total core specific gravity of 0.343 and an age 15 specific gravity of 0.397. This total core value is below the average of

the previous Japanese larch selections (0.374). However, the age 15 specific gravity of 0.397 was greater than anticipated. The reasons for the disparity in specific gravity results were not readily apparent and probably would require a microscopic examination of the wood structure. Whether this tree will be retained in the program is still indefinite.

Total core specific gravity of the 1981 European larch selections measured averaged 0.392; rings 14-16 averaged 0.399. These averages are slightly lower than those obtained for trees selected in 1980 (0.404 - total core and 0.432 - rings 14-16). However, several of the selected trees had total core specific gravity ranging from 0.358 to 0.366, which brought the average down. Again, these trees will have to excel in other respects to be retained in the program.

Fiber Length

The cores used for specific gravity measurements were then sectioned for fiber length determinations. Rings 11-15 were removed from two cores, and rings 14-16 were used from the remaining two cores. The sectioned cores were macerated and 600+ intact fibers measured for each determination. Intact fibers are measured on wood samples to give a better indication of the tree's true fiber length. This is contrasted with pulp samples where all fibers 0.3 mm and longer are measured to give an indication of actual fiber length going into the papermaking process.

Arithmetic average fiber length of rings 11-15 of the 1981 Japanese larch selection averaged 2.91 mm; rings 14-16 averaged 3.16 mm. Fiber lengths of rings 11-15 of the 1981 European larch selections averaged 2.59 mm, whereas rings 14-16 averaged 2.70 mm. Based upon fiber lengths of 16 European larch selections and 13 Japanese larch selections, Japanese larch seems to have a slight advantage over European larch in fiber length. However, fiber lengths for both species are

comparable to those reported for any young, fast-growing, short-rotation conifer.

Figure 11 depicts fibers from larch selection LD-11-81, rings 14-16.



Figure 11. Illustrated are typical L. decidua fibers used in making fiber length determinations. Only intact fibers were measured. Magnification - 50X.

Extractives

Extractive levels have an influence on pulp yield and bleaching characteristics of kraft pulps. A procedure has been developed for comparing differences between parent trees. The procedure used in obtaining hot-water and alcohol-benzene extractives involves removing the first ten rings from four cores collected for specific gravity and fiber length information and obtaining alcohol-benzene and hot-

water extractives separately (not consecutively) on a composited sample of all four cores using TAPPI Standards T 204 os-76 (alcohol-benzene) and T 207 os-75 (hot-water).

Alcohol-benzene extractives for the 1981 European larch selections averaged 3.4%, whereas the 1981 Japanese larch selection had an alcohol-benzene extractives content of 4.0%. This compares with 4.4% for the 1980 selected European and Japanese larch.

Average hot-water extractives for the 1981 European larch selections averaged 4.4%, whereas the 1981 Japanese larch selection had a hot-water extractives content of 2.6%. The 1981 values for hot-water extractives were much lower than the 1980 values. The differences obtained were apparently due to a change from one Tappi method to another. Rerunning some samples revealed that we should be employing the method used in 1981 (T 204 os-76). This means we will have to re-collect increment core samples from several trees selected and sampled in 1980. The hot-water extractives data summarized in Table III are based upon 1981 values only. With the addition of wood samples from seven Japanese larch and four European larch presently being processed, meaningful comparisons will be possible.

Extractives have been measured routinely on chip samples of trees cut for pulping studies. The chip samples represent the entire bole without bark to a 4-inch top of three composited trees. Given in Table IV for comparison purposes are the values obtained on these trees. Since these measurements represent the entire bole, it is not surprising that they are fairly low.

Larch continues to be a viable, alternative fiber source based upon information gathered on its wood quality as well as through growth and pulping results.

Table III summarizes wood quality obtained from young Japanese and European larch as part of this project.

TABLE III

WOOD QUALITY COMPARISONS
SELECTED TREES

Property	Japanese Larch	European Larch
Age 15 Specific gravity ^a	0.38 (0.29-0.43)	0.41 (0.35-0.50)
Age 15 Fiber length, mm ^b	2.96 (2.54-3.26)	2.74 (2.48-2.97)
Alcohol-benzene extractives, % First 10 rings ^c	4.4 (3.3-5.6)	4.4 (2.5-7.0)
Hot-water extractives, % First 10 rings ^c	2.6	4.4 (2.3-6.4)

^aGreen volume basis

^bArithmetic average of intact fibers only

^c1981 data only

TABLE IV

EXTRACTIVES INFORMATION^a
PULPING TREES

Species	Alcohol-Benzene Extractives, %	Hot-Water Extractives, %
23-year-old Japanese larch	3.0	7.4
18-year-old European larch	1.8	3.9
23-year-old hybrid larch	2.5	4.2

^aSamples used were chip samples representing the entire bole without bark to a 4-inch top of three composited trees for each species.

Mechanical Properties

Although the strength properties of larch are not of direct concern in this project, some information has been gathered to assist companies in assessing the potential of Japanese and European larch in integrated usage for solid wood and paper products. According to Schreiner (7), improvement in mechanical properties of forest trees is possible through a combination of genetics and silviculture. However, for the most rapid improvement, more specific information is needed on the relationship of individual wood characteristics to mechanical properties. Markwardt and Wilson (8) give a conservative estimate of individual variation in mechanical properties. The values are general figures derived from a number of species. Table V summarizes these estimates.

TABLE V

VARIATION IN MECHANICAL PROPERTIES FROM SPECIES AVERAGE

Property	Percent Variation
Static bending:	
Fiber stress at proportional limit	9
Modulus of rupture	7
Modulus of elasticity	9
Work to maximum load	15
Impact bending:	
Fiber stress at proportional limit	8
Work to proportional limit	12
Height of drop	13
Compression parallel to grain:	
Fiber stress at proportional limit	12
Crushing strength	7
Compression perpendicular to grain:	
Fiber stress at proportional limit	14
Hardness:	
End	10
Side	9
Shearing strength parallel to grain	7
Tension perpendicular to grain	12

Olson et al. (9) measured 23 European larch trees with an average age of approximately 30 years from seed. The trees had been grown in an area of comparatively low fertility and, as a consequence, had an average height of only 47 feet and an average b.h. diameter of 11.4 inches. Summarized in Table VI are the values obtained for basic strength properties. As a comparison, the strength properties of forest-grown trees are also given.

TABLE VI
STRENGTH PROPERTIES OF PLANTATION-GROWN
VS. FOREST-GROWN EUROPEAN LARCH^a

Property ^b	Plantation Grown	Forest Grown
Static bending:		
Stress at proportional limit (psi)	4,300	5,700
Modulus of rupture (psi)	8,500	11,400
Modulus of elasticity (1,000 psi)	1,010	1,390
Compression parallel to grain:		
Stress at proportional limit (psi)	2,380	3,400
Maximum crushing strength (psi)	4,280	6,370
Compression perpendicular to grain:		
Stress at proportional limit (psi)	890	780
Hardness:		
End (pounds)	800	1,100
Side (pounds)	610	920
Shear parallel to grain (psi)	1,510	1,455
Cleavage (pounds per inch of width)	220	260
Tension perpendicular to grain (psi)	380	390
Toughness (inch pounds)	127	--

^aData taken from Olson et al. (9).

^bMeasurements made at 12% moisture content for everything except toughness, which was measured at moisture contents ranging from 9 to 20%.

PULP PROPERTIES OF JAPANESE LARCH KRAFT PULPS

Introduction

Most previous larch investigations have examined the wood and pulping characteristics of trees of ages in excess of 50 years. Little is known about wood and pulp properties of European, Japanese, and hybrid larch grown primarily for fiber at rotation ages of 18 to 25 years. The objectives of the larch pulping studies are to determine the usefulness of 18 to 25-year-old larch in the production of bag and bleachable grade papers. Earlier, four sources of larch, including 18-year-old European larch, 23-year-old hybrid larch, 8-year-old hybrid larch, and 55-year-old jack pine (control), were pulped and the results described in Progress Report One (p. 44-64). The report that follows describes the Japanese larch pulping results and compares the data with those from the previously pulped and discussed jack pine and 23-year-old hybrid larch.

Japanese larch wood chips were investigated for their usefulness as bag paper by cooking to a kappa number of approximately 50 and for use as part of the furnish of bleachable grade pulps by cooking to a kappa No. 30. Jack pine was selected as a basis for comparison because of its common use in the Lake States and the Northeast. The 75% jack pine/25% larch mixtures selected were used because it appeared that, with the relatively limited supply of larch, the species would not be cooked alone but in mixtures with other conifers and that very likely these mixtures would contain 25% or less of larch. Data plotting difficulties (space and confusion) preclude comparing the Japanese larch data with all previous larch data. To keep the comparison simple, Japanese larch data were compared with jack pine and 23-year-old hybrid larch values. Progress Report One revealed that 18-year-old European larch had higher pulp yield (3-4%) and cooking rates and strength properties very similar to those of jack pine.

Experimental Materials

The wood pulps used in this comparison came from two sources of larch and a mill-run source of jack pine. Table VII summarizes the age, tree size, percent heartwood, and percent compression wood for the three types of material used in the study. The 22-year-old Japanese larch and hybrid larch were from an Institute planting near Rhinelander, Wisconsin. The jack pine was harvested in northern Wisconsin, and came from the Thilmany Pulp & Paper Company wood pile at Kaukauna, Wisconsin.

TABLE VII
TREE SIZE AND WOOD QUALITY DATA^a

Type of Material	Age, years	Height, feet	Diam., inches	Bark, %	Specific Gravity	Breast Height, (4.5 feet)	Compression wood, %	Heart-wood, %
						Fiber Length, Age 15, mm		
Hybrid larch	23	55.6	7.0	10.1	0.413	2.75	0.4	47.6
Japanese larch	22	56	7.8	10.0	0.384	3.16	-0-	52.3
Jack pine control	55	--	--	--	0.436	--	7.5	28.7

^aValues based on an average of three trees for the Japanese and hybrid larch, and eight pulpwood bolts for the jack pine.

All materials were debarked, chipped, and screened prior to pulping. Chips passing the 3/4-inch screen and retained on the 1/2 and the 1/4-inch screens were the fractions that were pulped.

Cooking and Bleaching Conditions

Pulping runs were carried out in a stainless steel vessel of about 72 liters capacity, fitted with external circulation and indirect heating. The chips

were charged into a stainless steel basket, which closely matched the interior contours of the digester and which could be removed with the contents following cooking. The cooking liquors were prepared from a solution of sodium hydroxide and sodium sulfide of known concentration and density, together with the appropriate amount of dilution water. The pulping conditions employed are given in Table VIII. The pulp was screened through a 0.006-inch cut screen plate in a small Valley flat screen. The rejects were oven dried, weighed, and discarded. The accepted fiber was then used to determine the physical properties of the pulps using TAPPI standard methods after beating in a PFI mill at 10% consistency.

TABLE VIII
PULPING CONDITIONS

Constant Conditions	
Wood charge, kg o.d.	4.0
Water-to-wood ratio, cc/g	4.0
Effective alkali, % o.d. wood	16.0
Sulfidity, %	25.0
Time to 172°C, min	90
Cooking temperature, °C	172

The kappa 30 pulps were bleached using a CEDED sequence prior to physical property evaluation. Bleaching runs were done using heat-sealable polyester bags. Pulp in a crumb form was charged into the bags, diluted with deionized water, and the required bleach solution added to give the appropriate bleach consistency. The bleaching conditions and chemical charges employed are shown in Table IX. Upon completion of the bleaching time, the bag was removed, opened, and the sample of pulp removed from the bleaching chemical. The pulp was thoroughly washed and returned to

the bag and the remaining steps in the 5-stage bleaching sequence completed in a similar manner. Pulp from the final chlorine dioxide stage was diluted to a 1% consistency and acidified to pH 3 by bubbling SO₂ gas through the pulp suspension to quench any remaining chlorine dioxide activity. Brightness and handsheet strength properties were determined according to TAPPI standard methods.

TABLE IX
BLEACHING CONDITIONS

Bleach Stage	Bleach Chemical	Chemical Charge, % on o.d. pulp ^a	Consistency, %	Temp., °C	Time, minutes
1	Chlorine (C) Sulfur dioxide	8.3	3.0	Ambient	45
2	NaOH (E)	4.7	10	70	70
3	Chlorine dioxide (D ₁)	1.5	10	60	180
4	NaOH (E ₂)	1.0	10	60	60
5	Chlorine dioxide (D ₂)	0.5	10	60	180
6	Sulfur dioxide	0.5 to pH 3	1	Ambient	1

^aPulp o.d. weight 500 g.

Results and Discussion

Introduction

Space limitations make it desirable to reduce and summarize the many observations and extensive data generated in this study. With such an abbreviated approach, some valuable data must be eliminated. As a partial solution to this problem, the decision has been made to prepare an interim Project 3409 report that

ould go into greater detail than is appropriate at this time. Eventually, the data
ill be published.

od and Fiber Properties

In addition to the wood and fiber properties summarized in Table VII,
lues based upon disk samples taken at 4.5 feet (breast height), fiber properties
the pulps were measured. This information is summarized in Table X.

TABLE X
PULP FIBER DIMENSIONS

Material	Fiber Length, mm		Width, μm	Thickness, μm	Coarseness, mg/100 m	Kappa No.
	Arith.	Weighted				
brid	1.7	2.2	46.7	5.5	24.6	53.4
arch	1.7	2.2	47.7	5.1	21.2	34.6
apanese larch	1.8	2.3	48.8	4.6	24.1	55.7
	1.8	2.3	49.1	4.8	23.7	32.5
ack pine	1.9	2.2	42.1	4.5	22.0	51.1
ontrol	1.9	2.3	44.3	5.7	20.5	34.4
5% Hybrid larch/ 5% jack pine	1.9	2.3	40.3	5.3	--a	52.2
	2.1	2.5	44.2	5.1	--a	31.1
5% Japanese larch/ 5% jack pine	2.0	2.4	42.8	4.7	24.4	53.4
	1.9	2.2	43.7	4.7	21.4	35.3

Original values were found to be in error and are being rechecked.

The specific gravity values for the Japanese larch were lower than for the
ybrid larch. The jack pine wood samples were higher in specific gravity than any
f the larch samples investigated. The 22-year-old Japanese larch had no compres-
ion wood, suggesting that. if compression wood had been present as in the other
rees used, the specific gravity would have been modestly higher.

The pulp fiber dimensions summarized in Table X were surprisingly similar for the several sources of larch and larch/jack pine mixtures. Fiber width of the Japanese hybrid larch appeared to be greater than those of the other pulps. Also, the fiber cell wall thickness of this material appeared to be lower than that of the other pulps evaluated. Most of the values given in Table X are consistent with expectation, even the coarseness of the Japanese larch. The values involving Japanese larch were higher than jack pine and comparable to hybrid larch and European larch. Fiber coarseness is weight per unit length (mg/100 m), and, normally, narrow fibers, thin cell walls, and low wood density are usually associated with low fiber coarseness.

Wood Chemical Comparisons

Pulp yields are related to cooking conditions and lignin and extractive levels in the original wood samples. Table XI summarizes this information for the four sources of experimental chips. The Japanese larch lignin level was greater than the other sources of larch and was 1.9% higher than jack pine. Japanese larch alcohol-benzene extractives levels were similar to those of jack pine and hybrid larch and greater than those of European larch. Similarly, hot-water extractives were 5% higher for Japanese larch than for jack pine and about 3.5% greater than hybrid larch and European larch. The lower pulp yield of Japanese larch described in the following section reflects the high lignin and hot-water extractive levels. It should, however, be pointed out that hot-water extractive levels reported for the European and hybrid larch were about 1/2 the levels found in the literature for older larch. Japanese larch extractives levels for old trees are not available but are presumed to be greater than those given in Table XI.

TABLE XI
CHEMICAL PROPERTIES OF WOOD

Type of Material	Lignin, %	Extractives, %	
		Alcohol-Benzene	Hot Water
Hybrid larch	27.94	2.47	4.18
European larch	27.60	1.80	3.90
Japanese larch	29.30	3.00	7.40
Jack pine control	27.45	3.54	2.31

Pulp Yields

The pulping procedure followed was to establish the goals of kappa number* 50 (bag papers) and 30 (bleachable pulps) and then vary cooking conditions (H-factor) to obtain pulps that could be used in pulp strength comparisons. Table XII summarizes these results. The pulp yield information provided several interesting results. Comparing unscreened pulp yields**, for example, consistently demonstrated a 3-4% yield advantage for the earlier pulped 18-year-old European and 23-year-old hybrid larch over the 55-year-old jack pine. The Japanese had a lower pulp yield than European larch and hybrid larch (2.8-3.5%) and a pulp yield that was approximately equal to or slightly higher than that of jack pine.

Equally important is having good pulping rate compatibility between larch and jack pine. Previously reported results on European and hybrid larch revealed pulping at approximately the same rate as jack pine. Japanese larch, however, pulped modestly slower than jack pine (particularly at lower kappa numbers) as is illustrated by Fig. 12. This suggest that preparing low kappa pulps from chip

*Kappa number reflects the lignin remaining in the pulp.

**Even though rejects are high for the 100% 23-year-old hybrid larch, in practice, these fibers would be returned to the digester and pulped further, and the fiber not lost.

mixtures containing Japanese larch will result in modest overcooking of the associated jack pine chips.

TABLE XII

PULPING DATA

Composition	Factor	Kappa No.	Unscreened Yield, % o.d. wood	Screened Yield, % o.d. wood	Screened Rejects, % o.d. wood
100% Jack pine	1850	34.4	43.8	43.2	0.6
	1450	49.2	47.1	46.2	0.9
25% Japanese larch	1925	35.3	43.3	42.8	0.5
	1350	53.4	45.0	43.5	1.5
100% Japanese larch	2000	32.5	45.7	43.5	2.2
	1350	55.7	48.3	43.2	5.1
25% Hybrid larch	1850	31.1	46.6	46.1	0.5
	1350	52.2	49.7	46.8	2.9
100% Hybrid larch	1850	34.6	48.5	47.1	1.4
	1200	53.4	51.8	41.5	10.3

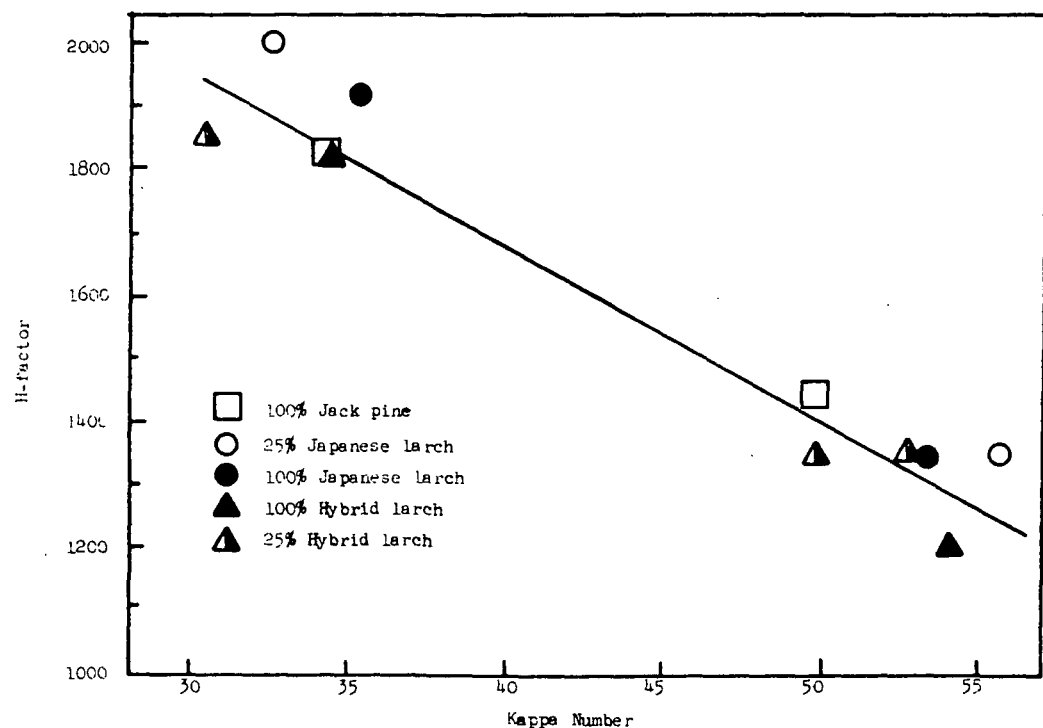


Figure 12. H-factor vs. kappa number.

Kappa 50 Pulp Strength

Table XIX of the Appendix summarizes the physical properties of unbleached kappa 50 pulps. Figures 13 through 16 illustrate several important strength property interrelationships. Figure 13 illustrates the amount of beating required to reach a given breaking length and demonstrates the differences which exist between the pulps in terms of maximum attainable breaking length. Japanese larch beats with more difficulty than jack pine but, in mixture with jack pine, beats at a rate similar to pure jack pine. Japanese larch, on the other hand, is easier to beat than hybrid larch. However, it did not have as high a tear as hybrid larch at equivalent breaking length. This latter relationship is illustrated in Fig. 14.

Another useful way to compare pulps is to plot tear factor vs. breaking length. This approach assumes the pulps are beaten to improve breaking length and, with increased beating, there will be a tearing strength loss. The better pulps are those that attain good breaking length (9-11 km) and retain tear factor values of 120 or more. Figure 14 illustrates such a comparison for the pulps involved in this study and demonstrated Japanese larch had a tear vs. breaking length strength relationship that was comparable to the 100% jack pine pulp. Pulp strength data for 100% hybrid larch pulp and pulp that is 75% jack pine and 25% hybrid larch were also plotted in Fig. 14. Pulp containing hybrid larch fiber did not attain as high an overall breaking length but had a higher tear (9-10%) at comparable breaking length when compared with the Japanese larch pulp.

Plotting burst factor vs. breaking length (Fig. 15) and breaking length vs. apparent density (Fig. 16) demonstrated that the Japanese larch pulps behaved in a manner typical of most conifers. Interestingly, however, the pulps containing

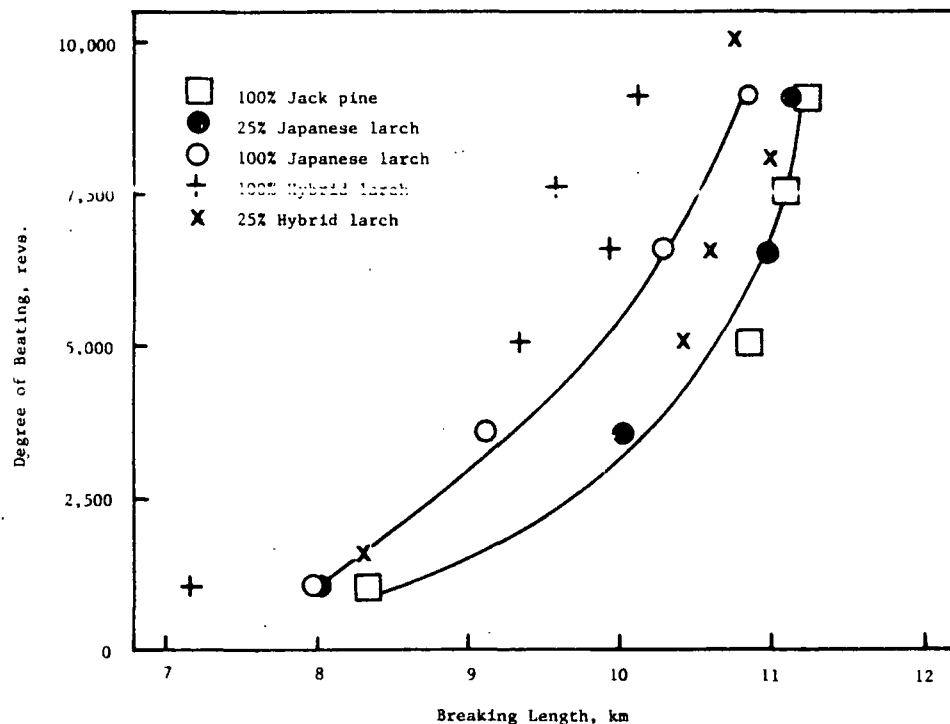


Figure 13. Degree of beating vs. breaking length at kappa 50. The curvilinear relationships illustrated are based upon Japanese larch and jack pine data only.

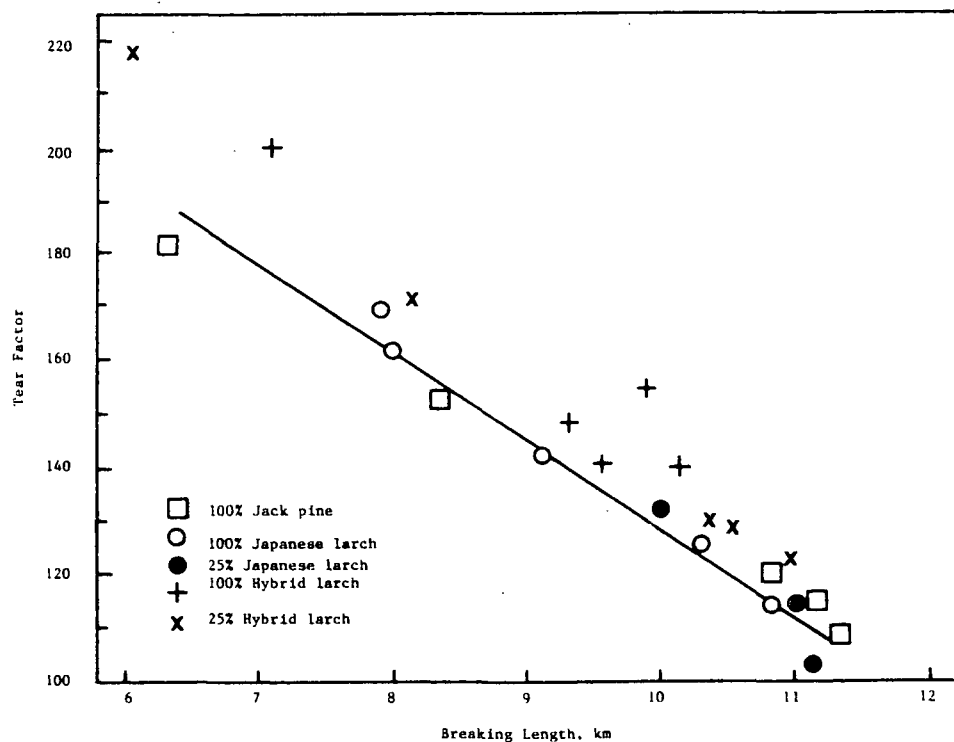


Figure 14. Tear factor vs. breaking length at kappa 50. The linear relationship illustrated is based upon Japanese larch and jack pine data only.

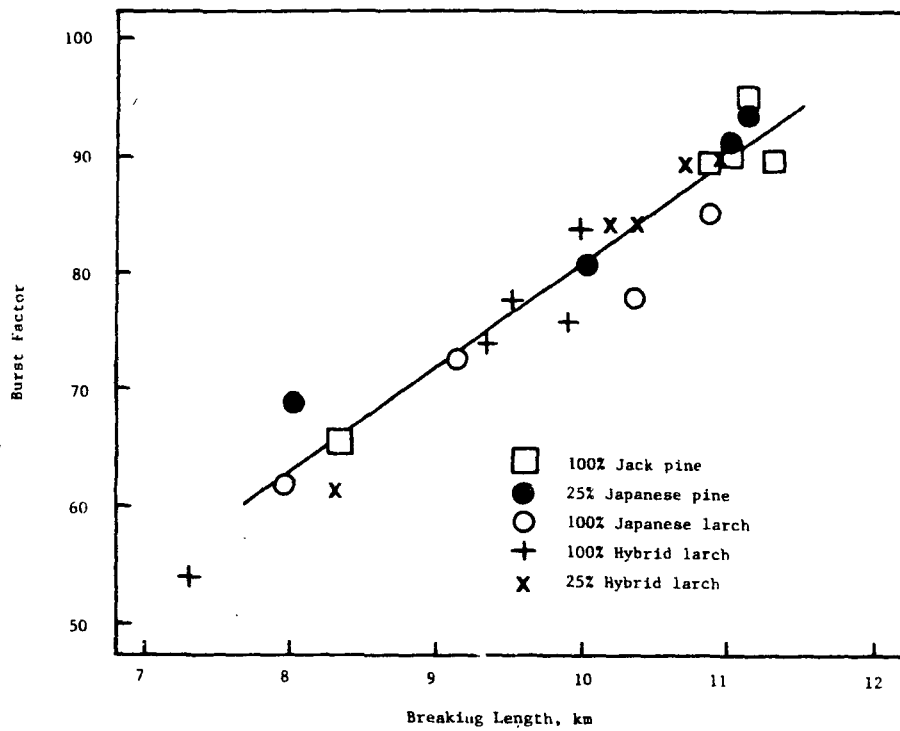


Figure 15. Burst factor vs. breaking length at kappa 50. The linear relationship illustrated is based upon Japanese larch and jack pine data only.

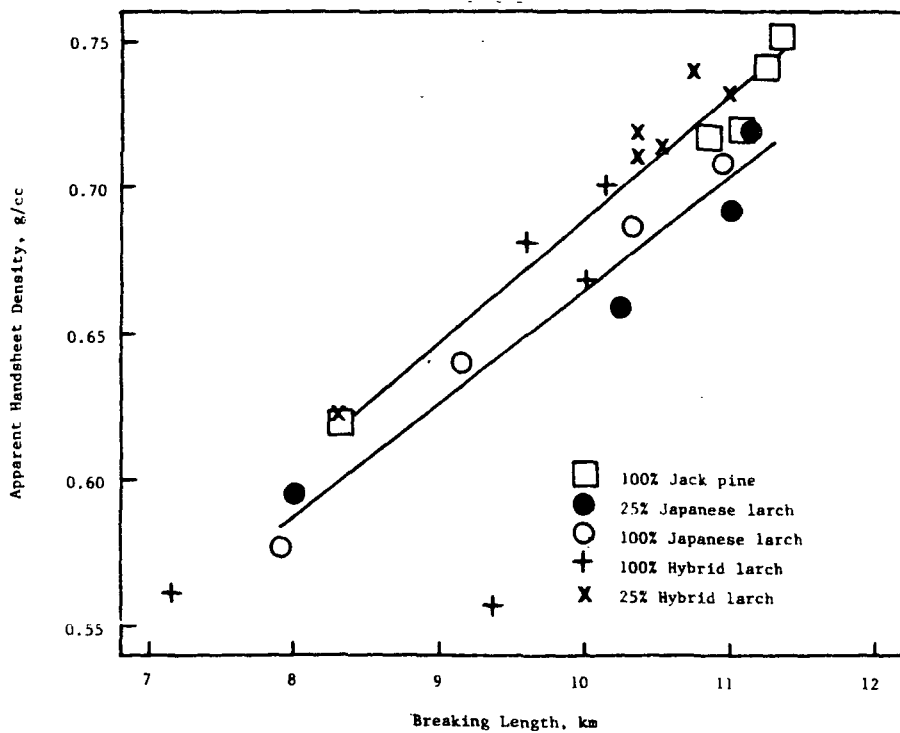


Figure 16. Apparent handsheet density vs. breaking length at kappa 50. The linear relationships illustrated are based upon jack pine and Japanese larch data only.

Japanese larch fiber appear, when sheet density is held constant, to have higher breaking length than the 100% jack pine pulps and the pulps containing hybrid larch fiber (Fig. 16). This, however, is a typical relationship. Conifer pulps having low tear normally would be expected to have above average breaking length.

Kappa 30 Bleaching Results

One papermaking concern, based upon remarks in the literature describing older-aged larch, was the difficulty encountered in bleaching larch pulps. This difficulty was attributed to high levels of hot-water extractives. The bleaching characteristics of kappa 30 Japanese larch pulps were investigated using the previously described CEDED bleaching procedure. This procedure was the same as that used previously (Progress Report One) with European larch and hybrid larch. Table XIII describes the results of the bleaching investigations and includes, for comparison purposes, data on jack pine, hybrid larch, and European larch. The bleached pulps were then evaluated for strength properties. Generally, the Japanese larch was more difficult to bleach, as illustrated by the lower brightness and higher chemical consumption when compared with jack pine, European larch, and hybrid larch.

Kappa 30 Pulp Strength Properties

The kappa 30 bleached pulps were evaluated using procedures similar to those used for the kappa 50 pulps. Appendix Table XX summarizes these evaluations and Fig. 17 through 20 illustrate the strength properties graphically. The kappa 30 pulp reacted to beating in a similar manner and developed strength similar to the kappa 50 pulps. The principal exception was the development of breaking length. The kappa 30 pulps, as illustrated in Fig. 17, developed higher breaking length than the kappa 50 pulps. The bleached kappa 30 pulp regression lines for burst vs. breaking length (Fig. 19) and for handsheet density vs. breaking length were almost

TABLE XIII
BLEACHING RESULTS OF 30 KAPPA PULPS

Wood Type	Unbleached Kappa No.	Chlorination Stage (C ₁) % Cl ₂ Consumed on o.d. Pulp	Extraction Stage No. (25 mL)	End pH	Chlorine Dioxide Stage (D ₁) % ClO ₂ Consumed on o.d. Pulp	Extraction Stage (E ₂) End pH	Chlorine Dioxide Stage (O ₂) % ClO ₂ Consumed on o.d. Pulp	G.E. Brightness, %
100% Jack pine	34.4	7.0	5.2	12.0	1.20	10.5	0.40	90.3
100% Japanese larch	32.5	7.3	7.2	12.8	1.40	12.1	0.45	84.4
100% European larch	31.4	7.3	5.3	12.2	1.44	10.9	0.40	88.2
100% Hybrid larch	34.6	7.0	5.7	12.2	1.32	11.3	0.21	88.3
75% Jack pine + 25% Japanese larch	35.3	7.5	6.2	12.8	1.40	12.1	0.32	87.9
75% Jack pine + 25% hybrid larch	31.1	7.0	4.6	12.7	1.27	10.4	0.23	90.2

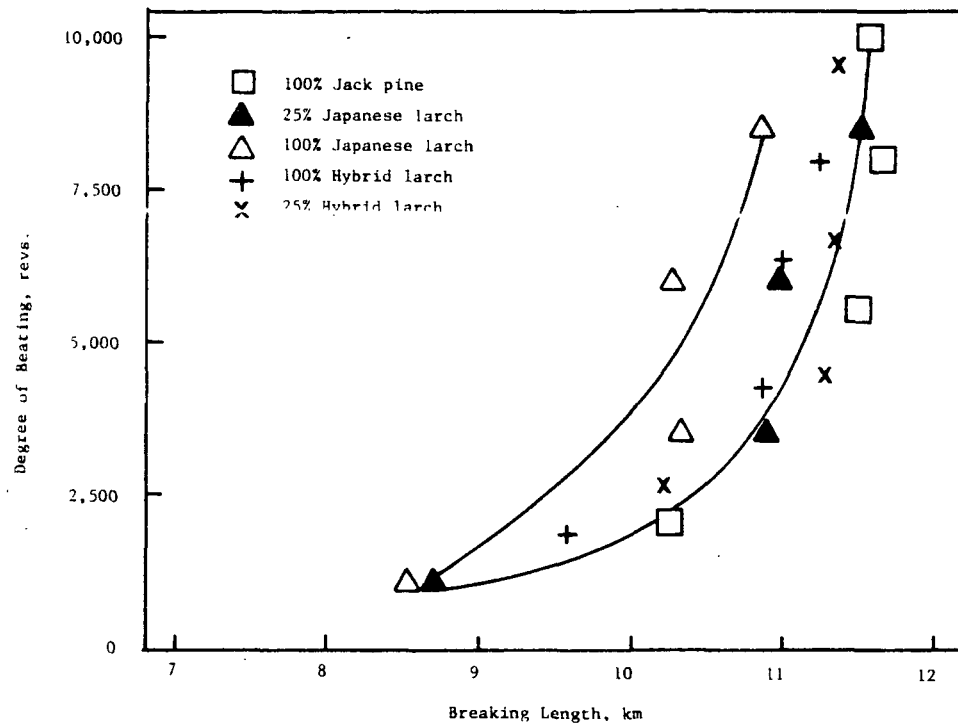


Figure 17. Degree of beating vs. breaking length at kappa 30. The curvilinear relationships illustrated are based upon Japanese larch and jack pine data only

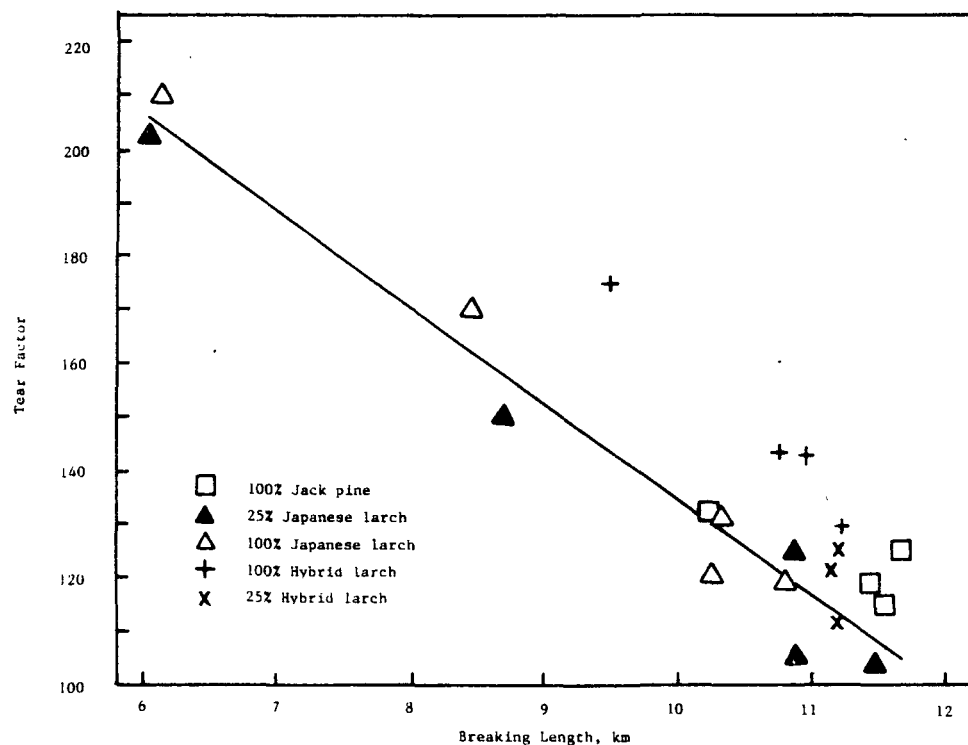


Figure 18. Tear factor vs. breaking length at 30 kappa. The linear relationship illustrated is based upon Japanese larch and jack pine data only.

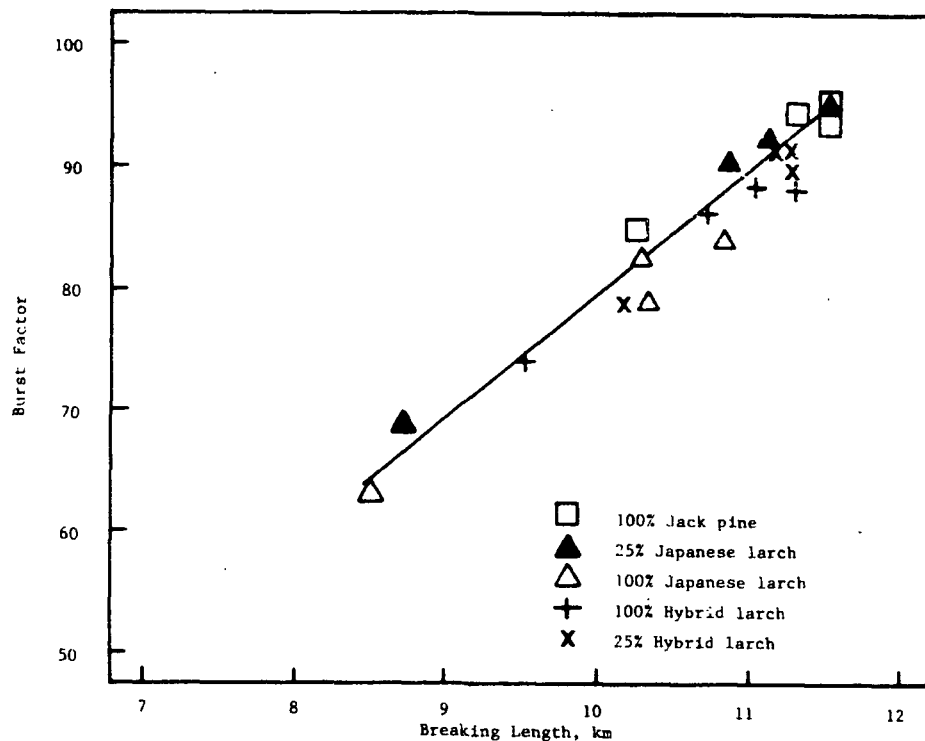


Figure 19. Burst factor vs. breaking length at kappa 30. The linear relationship illustrated is based upon Japanese larch and jack pine data only.

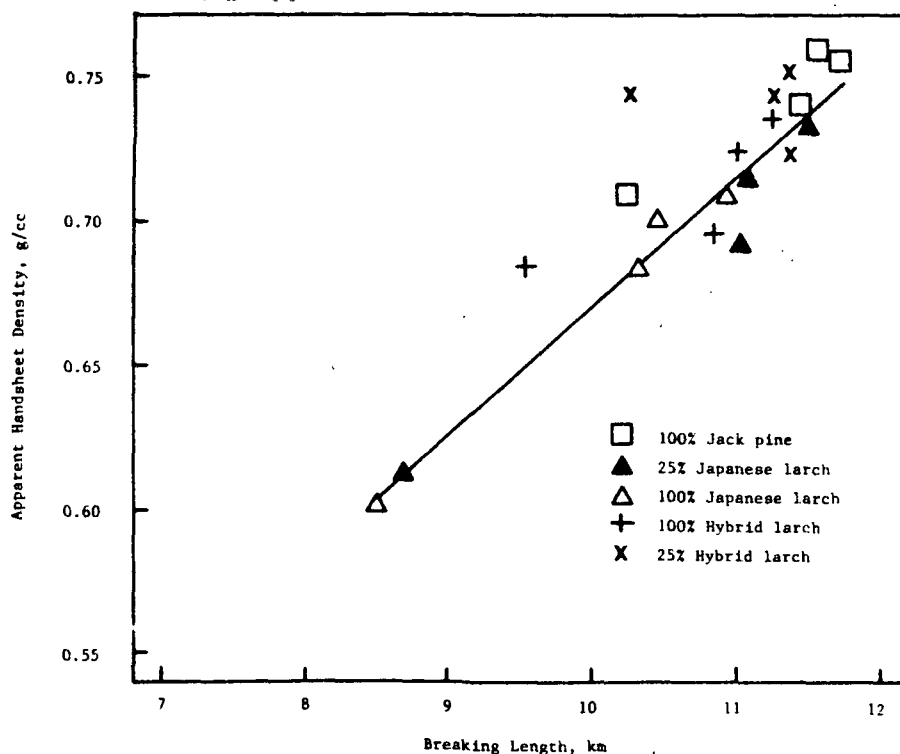


Figure 20. Apparent handsheet density vs. breaking length at kappa 30. The linear relationship illustrated is based upon Japanese larch and jack pine data only.

identical to the kappa 50 pulps regression lines. As was noted in the work with kappa 30 pulps containing hybrid larch and European larch fiber, the Japanese larch kappa 30 pulps also reacted to beating in a manner similar to the jack pine bleached pulp. This appears to have occurred because, when cooking to kappa 30 and bleaching, additional lignin was removed, and removing greater amounts of lignin reduced inherent differences between fiber sources. As a result, all sources reacted to refining in much the same way. Figures 17 through 20 confirm that the bleached kappa 30 pulps tended to respond to refining in a similar manner and have similar burst and breaking length and lower tearing strength than jack pine and hybrid larch kappa 30 pulps.

Strength Properties of Kappa 30 Bleached Conifer/Hardwood Pulp Mixtures

To evaluate the relative usefulness of the bleached kappa 30 pulps for improving the properties of bleached hardwood pulps, mixtures of 50% Japanese larch + 50% bleached hardwood and 50% (75% jack pine + 25% Japanese larch) + 50% bleached hardwood pulps were prepared. Appendix Table XX summarizes the results of these comparisons, and Fig. 21 through 24 illustrate the reaction of these pulp mixtures, in terms of strength properties, to refining. All of the bleached conifer/bleached hardwood mixtures responded in a similar manner as did the 100% conifer pulps. The 100% conifer pulps, however, had a considerably higher breaking length than did bleached conifer/bleached hardwood mixtures when compared at the same level of tear (Fig. 22). When burst factor was compared with breaking length (Fig. 23) and apparent handsheet density was plotted over breaking length, the 100% conifer pulps and the conifer/hardwood pulps could be described with a single linear regression equation. The 100% conifer had the highest breaking length values (Fig. 23 and 24).

Summary

Kappa 50 pulps for use as bag papers and kappa 30 pulps for bleached grade pulps were produced by pulping Japanese larch and jack pine control chips along with a 25% larch/75% jack pine mixture. Standard TAPPI methods were used in evaluating the pulps. The results were compared with those of earlier reported hybrid larch pulps and are summarized as follows:

1. The Japanese larch chip sources and the mixtures with jack pine cooked at a slightly slower rate than jack pine.
2. Unscreened Japanese larch yields were approximately 3% lower than hybrid larch and about 1% greater than jack pine.
3. Japanese larch wood chip alcohol-benzene extractive levels were equal, and hot-water extractives levels were more than double the levels in jack pine.
4. Japanese larch pulps had comparable fiber length, greater fiber width, and higher coarseness than jack pine pulps.
5. The kappa 50 pulps of Japanese larch were more difficult to beat and developed lower ultimate breaking length than the jack pine and the 25% larch/75% jack pine mixtures.
6. The kappa 50 pulps from Japanese larch and the mixtures with jack pine had tear comparable to jack pine but lower tear than the hybrid larch.
7. Japanese larch pulps were more difficult to bleach, i.e., attained lower brightness and required more chemical, than the jack pine and European and hybrid larch pulps.

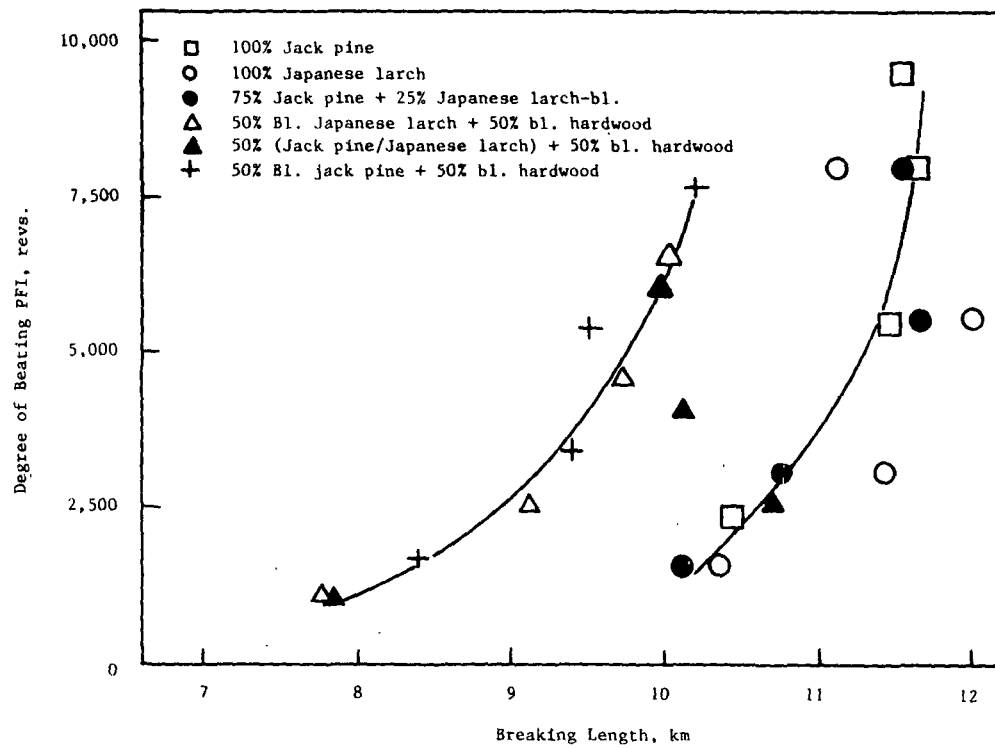


Figure 21. Degree of beating vs. breaking length.

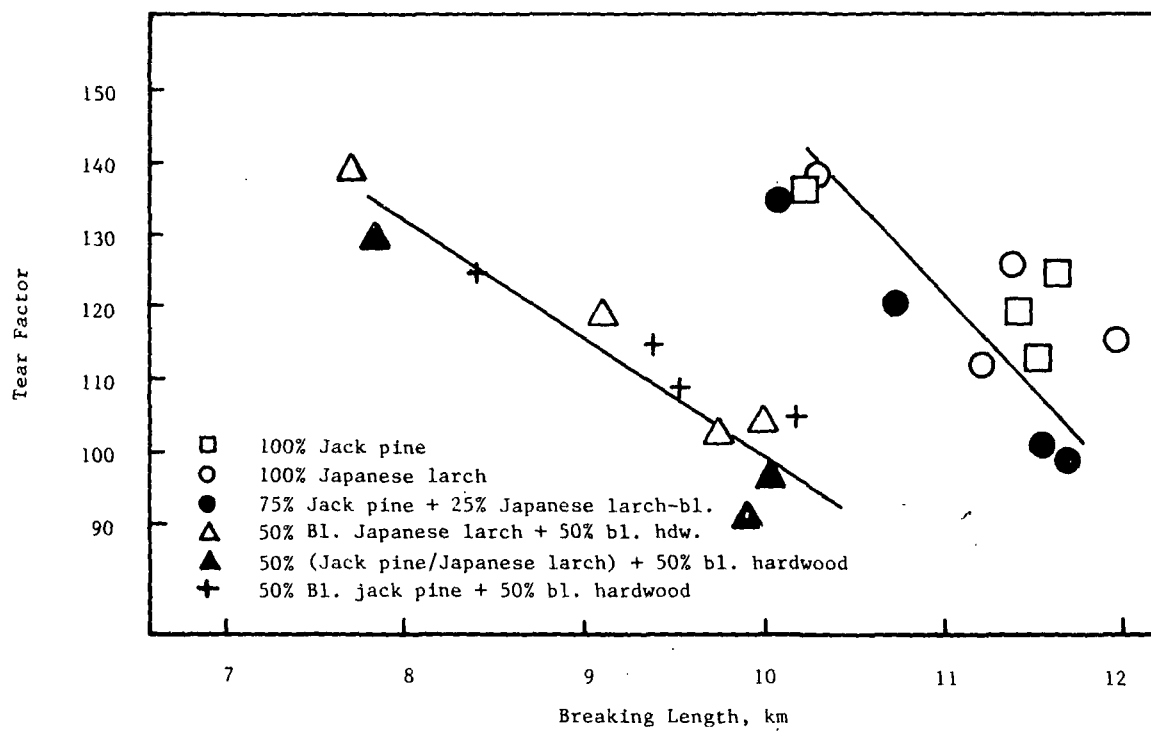
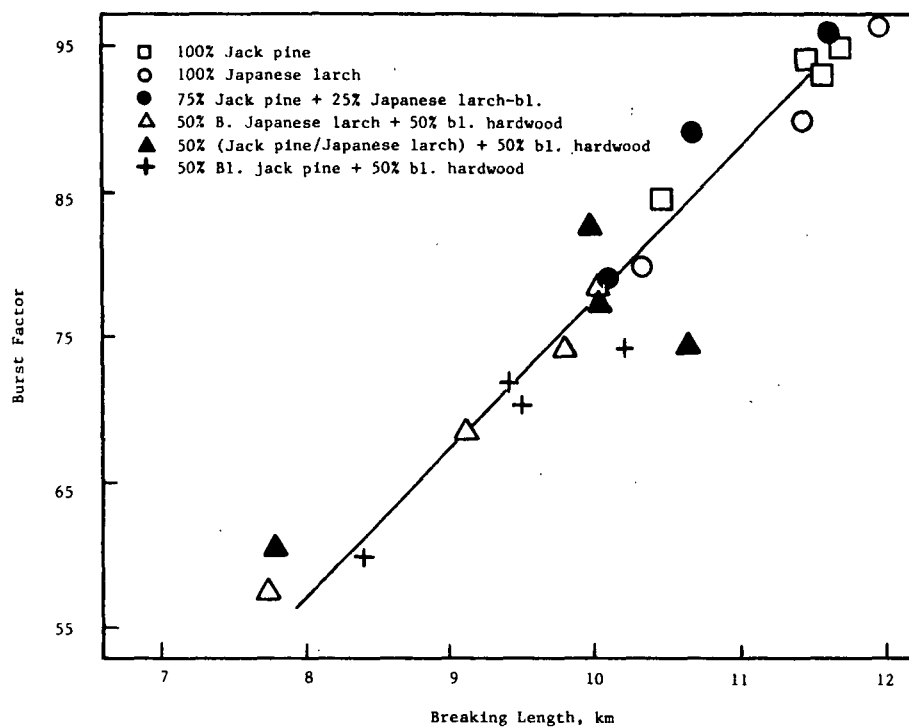
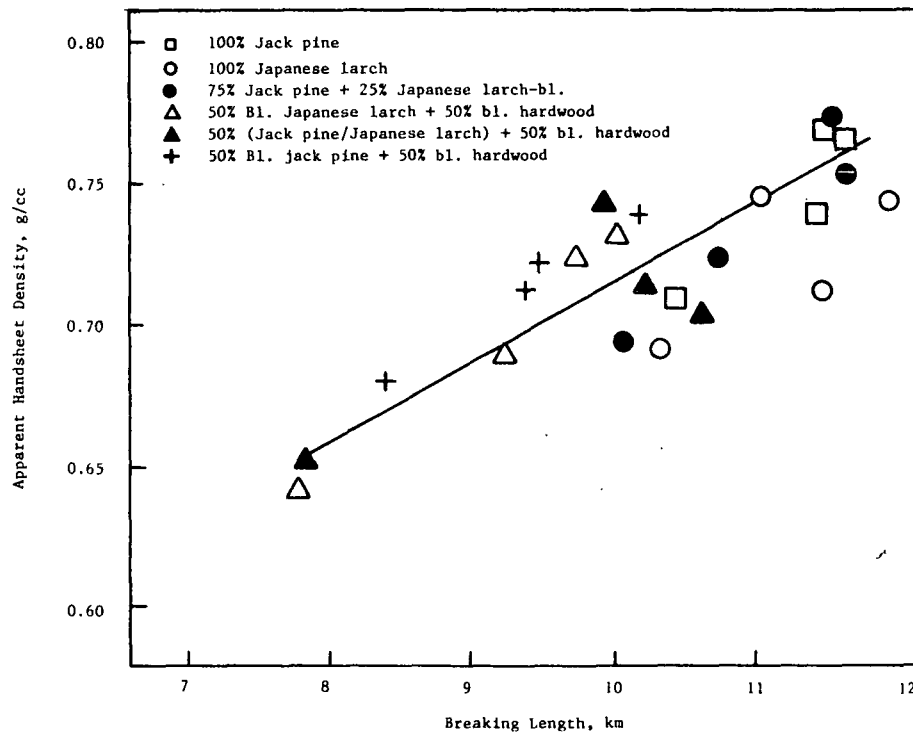


Figure 22. Tear factor vs. breaking length.

Figure 23. Burst factor vs. breaking length.Figure 24. Handsheet density vs. breaking length.

8. Pulping Japanese larch and larch/jack pine mixtures to a kappa 30 followed by bleaching resulted in pulps that refined and had strength properties very similar to the jack pine control.
9. Bleached Japanese larch pulps and mixtures with jack pine gave strength properties that were equivalent to the unbleached properties.
10. When bleached Japanese larch and bleached larch/jack pine pulps were mixed with bleached hardwood pulps, the strength properties were comparable to the strength of pulps prepared from bleached jack pine/bleached hardwood pulp mixtures.

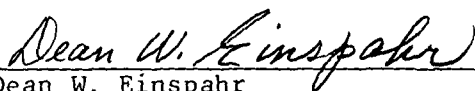
ACKNOWLEDGMENTS

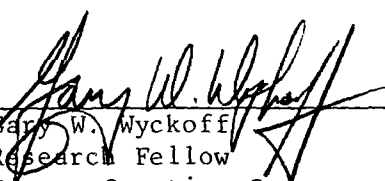
The authors of this report are indebted to Robert Avery and John Lorenz for their assistance with grafting, nursery maintenance, and field measurements and collections. The authors also wish to acknowledge the assistance of the Institute's Pulping Group for their work on the kraft pulping of larch, the Fiber Science Group for fiber dimension measurements, and the Analytical Chemistry Group for lignin and extractives measurements. Great appreciation is also expressed to the U.S. Forest Service, Wisconsin DNR, and various company foresters for their help in locating selected trees.

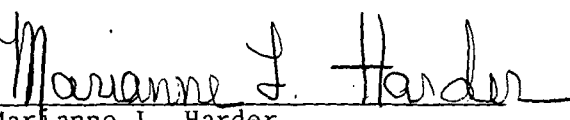
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APPENDIX

TABLE XIV

EUROPEAN LARCH PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Distribution Group ^b	Cooperator and Location
LD-10-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-1-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-2-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-3-80	Wroclaw, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-4-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-5-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-6-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-7-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-8-80	SSUI ^a		Wisconsin DNR, LaCrosse, WI
LD-9-80	SSUI ^a		Wisconsin DNR, LaCrosse, WI
LD-10-80	SSUI ^a		Wisconsin DNR, LaCrosse, WI
LD-11-80	Tyrolea, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-13-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-14-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-15-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-16-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-17-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-18-80	SSUI ^a	SSUI	
LD-19-80	Nodebo, Denmark	Sudeten ^a	U.S. Forest Service, Rhinelander, WI
LD-20-80	Kronborg, Denmark	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LD-21-80	Palsgaard, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-22-80	Nodebo, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-23-80	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-24-80	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-25-80	SSUI ^a	SSUI	Hammermill Paper Co., Cattaraugus, NY
LD-26-80	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-27-80	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-28-80	SSUI ^a	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-29-80	SSUI ^a	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-30-80	SSUI ^a	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-1-81	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-2-81	Zagnansk, Poland	SSUI	U.S. Forest Service, Rhinelander, WI
LD-3-81	Arretet, Denmark	SSUI	U.S. Forest Service, Rhinelander, WI
LD-4-81	Palsgaard, Denmark	SSUI	U.S. Forest Service, Rhinelander, WI
LD-5-81	Nodebo, Denmark	SSUI	U.S. Forest Service, Rhinelander, WI
LD-6-81	Palsgaard, Denmark	SSUI	U.S. Forest Service, Rhinelander, WI
LD-7-81	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-8-81	SSUI ^a	SSUI	Hammermill Paper Co., Potter, PA
LD-9-81	SSUI ^a	SSUI	Hammermill Paper Co., Potter, PA
LD-10-81	SSUI ^a	SSUI	Hammermill Paper Co., Potter, PA
LD-11-81	SSUI ^a	SSUI	Hammermill Paper Co., Warren, PA
LD-12-81	SSUI ^a	SSUI	Scott Paper Co., Waterville, ME
LD-13-81	SSUI ^a	SSUI	Scott Paper Co., Waterville, ME

^aSeed source under investigation.^bFour separate distributional groups are recognized within the geographical range of European larch: Alpen, Sudeten, Tatra and Polen plus several smaller outliers in Rumania. Major genetic differences are found between and within these groupings (13).

Appendix (Continued)

TABLE XV
JAPANESE LARCH PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Cooperator and Location
LL-4-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-4-59,S-2	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-12-59,S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LL-1-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-2-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-3-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-4-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-5-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-6-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-7-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-8-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-9-80	Latitude 35° 54' longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-10-80	Latitude 35° 54' longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-11-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-12-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-13-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-14-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-15-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-16-80	SSUI ^a	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-17-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-18-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-19-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-20-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-21-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-22-80	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-23-80	SSUI ^a	Glatfelter Pulp Wood Co., Hershey, PA
LL-24-80	SSUI ^a	Glatfelter Pulp Wood Co., Hershey, PA
LL-1-81	SSUI ^a	U.S. Forest Service, Rhinelander, WI
LL-3-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-4-81	Gumma Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-6-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-7-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-8-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-9-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-10-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-11-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-12-81	SSUI ^a	Scott Paper Co., Oxford City, ME

^aSeed source under investigation.

Appendix (Continued)

TABLE XVI

ACID PHOSPHATASE

EXTRACT IN 70% ACETONE

DO NOT DIALYZE

ISOELECTRIC FOCUSING
5.5-8.5 pH GEL^a

STAIN PER HAMAKER & SNYDER

^aA 4.0-6.5 pH gel has been a
better range for some material.

PEROXIDASE

EXTRACT IN 30% DMSO

DO NOT DIALYZE

ISOELECTRIC FOCUSING
4.0-6.5 pH GEL

STAIN PER HAMAKER & SNYDER

Appendix (Continued)

TABLE XVII

CYTOCHROME OXIDASE

EXTRACT IN 30% DMSO

DO NOT DIALYZE

ISOELECTRIC FOCUSING
4.0-6.5 pH GEL

STAIN PER HAMAKER & SNYDER

MALATE DEHYDROGENASE

EXTRACT IN 70% ACETONE

DO NOT DIALYZE

ISOELECTRIC FOCUSING
4.0-6.5 pH GEL

STAIN PER HAMAKER & SNYDER

Appendix (Continued)

TABLE XVIII

GLUTAMIC-OXALACETIC TRANSAMINASE

EXTRACT IN 30% DMSO

DO NOT DIALYZE

ISOELECTRIC FOCUSING
WIDE-RANGE AGAROSE GEL

STAIN PER HAMAKER & SNYDER

LEUCINE AMINO PEPTIDASE

EXTRACT IN 30% DMSO

DO NOT DIALYZE

ISOELECTRIC FOCUSING
WIDE-RANGE AGAROSE GEL

STAIN PER HAMAKER & SNYDER

Appendix (Continued)

TABLE XIX

PHYSICAL PROPERTIES OF UNBLEACHED JAPANESE LARCH

Wood Type	Kappa No.	No. of Revs.	CF, mL	Density, g/cc	Burst Factor	Tear Factor	Breaking Length, km	TEA, kg M/m ²	Z-span Breaking Length, km
100% Japanese larch	55.7	0	740	0.458	38.4	208.8	5.29	4.25	16.99
		1000	710	0.577	61.5	168.7	7.90	9.20	17.27
		3500	600	0.640	72.5	142.5	9.13	11.93	17.46
		6500	330	0.687	77.9	125.5	10.30	14.81	17.72
		9000	210	0.709	85.6	114.8	10.83	15.51	17.58
75% Jack pine + 25% Japanese larch	53.4	0	750	0.462	40.3	197.6	5.26	3.79	17.05
		1000	725	0.583	68.5	162.2	7.99	8.70	18.50
		3500	610	0.659	80.8	132.5	10.01	12.64	18.83
		6500	405	0.692	91.4	114.0	10.99	15.76	18.98
		9000	230	0.722	93.5	103.1	11.13	15.78	19.26
100% Japanese larch	32.5	0	715	0.490	41.0	209.8	6.10	5.09	16.73
		1000	655	0.606	63.9	169.7	8.53	10.18	17.46
		3500	485	0.686	79.0	130.6	10.33	13.67	17.91
		6000	300	0.697	82.8	121.9	10.26	13.52	17.88
		8500	210	0.718	83.5	119.5	10.81	14.44	18.31
75% Jack pine + 25% Japanese larch	35.3	0	710	0.504	39.9	203.1	6.04	4.87	17.97
		1000	685	0.624	69.1	149.9	8.68	9.81	19.35
		3500	535	0.693	90.7	124.6	10.84	15.26	19.45
		6000	325	0.714	93.3	105.1	10.91	14.40	19.72
		8500	205	0.733	95.8	104.9	11.52	15.43	19.29
100% Hybrid larch	53.4	0	760	0.464	31.9	216	5.06	3.3	17.2
		1000	710	0.564	53.2	202	7.14	7.8	18.2
		5000	565	0.557	73.5	149	9.32	12.8	18.0
		6500	465	0.670	74.2	155	9.90	17.3	18.7
		7500	390	0.686	77.4	141	9.58	13.5	18.3
100% Jack pine	49.2	0	725	0.529	46.2	182	6.30	5.0	19.8
		1000	705	0.629	65.4	153	8.31	9.5	20.2
		5000	510	0.717	87.0	122	10.82	14.6	20.9
		6000	455	0.720	88.8	114	11.10	14.9	19.8
		7500	345	0.744	95.2	111	11.15	15.6	20.0
		9000	260	0.754	89.2	108	11.28	15.3	21.2

TABLE XX

PHYSICAL PROPERTIES OF BLEACHED JAPANESE LARCH

[illegible]

GLOSSARY

FOREST GENETICS TERMS

- Clone - A group of plants derived from a single individual (ortet) by asexual reproduction. All members (ramets) of a clone have the same genotype and, consequently, tend to be uniform.
- Compression wood - Wood of dense structure formed at the bases of some trees and on the underside of branches in conifers.
- Cyclophysis - Abnormal growth that occurs in a graft when scion material is collected from too low an area in the crown.
- Cytochromes - Cytochrome a, b, and c are heme-containing proteins widely occurring in cells and acting as oxygen carriers during cellular respiration.
- F₁ generation - The first generation of a mating. If each parent is true breeding (homozygous), the F₁ individuals always resemble each other.
- F₂ generation - The second generation successive to the parents and produced by crossing or selfing the F₁ individuals. The individuals within an F₂ generation characteristically vary greatly when their F₁ parent or parents are heterozygous.
- Full-sib - Progeny, irrespective of sex, having the same male and female parent but from separate fertilizations.
- Half-sib - Progeny, irrespective of sex, having only one parent in common.
- Hedging - Reducing a plant to a more juvenile stage by repeatedly cutting it back and forcing a large number of shoots.
- Heterozygosity - Presence in the same plant of both the dominant and recessive gene. A heterozygous individual characteristically does not breed true.
- Homozygosity - Presence in a plant of either the dominant or recessive gene but not both. A homozygous individual breeds true when mated with the same genotype for the character(s) in question.
- Inbreeding depression - Loss of vigor and/or fertility through intercrossing or selfing related organisms.
- Isozyme (isoenzyme) - Multiple forms of a single enzyme. Isozymes often have different isoelectric points and therefore can be separated by electrophoresis.
- Plagiotropism - A growth response to gravity, so that the axis of the plant member makes an angle other than 90° with the line of the gravitational field.
- Propagule - A plant part such as a bud, tuber, root, or shoot, used to reproduce an individual asexually.

Glossary (Continued)

Provenance - The original geographic source of seed or propagules.

Pseudophysis - Abnormal growth that occurs in a graft when scion material is collected from the wrong branch positions.

HELPING TERMS

Breaking length - The length of a strip, usually expressed in meters, which would break of its own weight when suspended vertically.

Bursting strength - The hydrostatic pressure in pounds per square inch required to produce rupture of the material when pressure is applied at a controlled increasing rate through a rubber diaphragm to a circular area.

Staged bleaching - Sequence of chlorination, alkali extraction, chlorine dioxide, extraction and chlorine dioxide.

Coarseness - The weight per unit length of a single fiber. Usually expressed as mg/100 m and is considered to be useful in predicting fiber behavior in papermaking.

Freeness - A measure of the rate with which water drains from a stock suspension through a wire mesh screen or a perforated plate. It is also known as "slowness" or "wetness" according to the type of instrument used in its measurement and the method of reporting results.

Furnish - The mixture of various materials that are blended in the stock suspension from which paper or board is made. The chief constituents are the fibrous material (pulp), sizing materials, wet-strength or other additives, fillers and dyes.

Handsheet - A sheet made from a suspension of fibers in water, with or without the addition of sizing, loading or coloring agents. Each sheet is formed separately by draining a pulp suspension on a stationary mold called a sheet mold. It is generally used for testing the physical properties of the pulp and/or the combinations of pulp with other material, in which case the sheet must be formed in accordance with standard procedures.

Kappa no. - Related to the amount of lignin left in the pulp. Decreasing numbers mean less lignin left in the pulp.

Tearing resistance - The force required to tear a specimen under standardized conditions. There are three terms in common usage: (1) internal (or continuing) tearing resistance, wherein the edge of the specimen is cut prior to the actual tear. The value is commonly expressed in grams of force required to tear a single sheet. (2) "Edge tearing resistance." (3) Torsion tearing resistance of paper or paperboard is the energy expended in propagating a tear when the tearing force is applied in such a manner as to create a twist or torque.

Glossary (Continued)

Tensile strength - The force, parallel with the plane of the paper, required to produce failure in a specimen of specified width and length under specified conditions of loading. This definition must be distinguished from that which is commonly used in engineering practice which expresses the tensile strength in force per unit area. In the paper industry, it is expressed as load per unit width or as "breaking length."

Zero-span tensile strength - The tensile strength of a sheet of fibrous material, measured with special jaws, at an apparent initial span of zero. It is an indication of the strength of the material comprising the fiber.